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ABSORPTION SPECTRA of the ANILINE DYES.

By

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DISSERTATION
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PART I.

THEORY and PRACTICE.

INTRODUCTION.

Definitional. When a beam of light comprising all wave-lengths from the remote infra red to the extreme ultra violet is incident upon a non-opaque object in such a manner that a portion of it, at least, passes through a layer of finite thickness and then emerges, two facts always present themselves; first, the intensity of the light of a given wave length just as it emerges from the absorbing medium considered is less than the intensity of the same light at the instant when it entered into this medium; second, the percentage diminution of intensity varies from one wave-length to another, in general, assuming, to avoid further qualifications, that the path followed through the medium is the same for the various wave-lengths.

In virtue of the first circumstance the substance traversed is called an "absorbing medium" (for light) and it is said to have "absorbed" some of the light. This means that the medium causes a portion of the energy associated with the light vibrations of a given wave-length, which are being transmitted by the substance, to manifest itself in some form other than that which it had at the beginning of transmission.

If, in a rectangular system of coördinates points be plotted having wave-lengths for abscissae and the corresponding percentages of energy transmitted by a layer of constant thickness as ordinates, and if a smooth curve be drawn in the coördinate plane through these points, an instructive diagram results, and the curve is named an "absorption curve". If the region of wave-lengths be as extended as we have suggested above, and if the dispersion of the experimental system be not too great, there will always be found portions of the absorption curve of a given substance which are either parallel to the axis of abscissae or slope very gently with reference to this axis, over a relatively wide range of wave-lengths, and other portions of the curve which are steeply inclined to the aforesaid axis. When the given material, under definite specifiable conditions, leads to an absorption curve which, throughout the region of wave-lengths corresponding to the sense of light in the human eye, is effectively parallel to the axis of abscissae, the substance is said to exhibit "general absorption". On the other hand, when the absorption curve for the visible spectrum has one or more maxima and minima, of which the respective ordinates differ by relatively great amounts, the material is said to present "selective absorption". Of course, the adjectives general and selective

in the senses just defined, are relative to each other, and if all known wave-lengths be taken into consideration then the former epithet loses most, if not all, of its pertinence.

Theoretical. Of the numerous questions which have been asked about the phenomena of absorption, and to which more or less satisfactory answers have been given, perhaps the simplest is the question concerning the quantitative relation between the intensities of the incident* and emergent light under definite conditions of wave-length and of thickness of absorbing layer. About the middle of the eighteenth century Bouguer and Lambert framed the hypothesis that a layer of unit thickness of an absorbing substance always absorbs a definite fractional part of the incident, homogeneous light. Two ideas which have since been elevated to the rank of laws are involved in the hypothesis, viz;

1. The ratio of the intensity after transmission through a layer of arbitrary thickness of a given substance, of the light of a chosen wave-length to the intensity of the incident light is independent of this last intensity.

2. The intensity of the emergent light decreases in geometrical progression as the thickness of absorbing layer tra-

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* We shall assume throughout this article that proper corrections have been made for "losses" by reflection, absorption in the walls of vessels retaining fluids, etc.

versed increases in arithmetical progression, provided, of course, all other quantities and conditions are maintained constant.

These two laws can be united in symbols as follows. Let i_λ denote the intensity of the light of wave-length incident normally upon, and entering into, a plane parallel layer of thickness dx in some absorbing medium and let $i_\lambda + di_\lambda$ symbolize the intensity of the light emergent from this layer. The second law enables us to write

$$di_\lambda = -\kappa_\lambda i_\lambda dx$$

The only way in which κ_λ could be a function of x is by its being dependent upon the intensity, i_λ, but the first law states that κ_λ is not dependent upon i_λ and therefore it is not a function of x, that is, κ is positive, and a constant so far as i_λ and x are concerned.

If I_λ and I'_λ mean the intensities corresponding respectively to the values $x_\circ$ and $x_\circ + l$ of x then

$$\int_{I_\lambda}^{I'_\lambda} \frac{di_\lambda}{\kappa_\lambda i_\lambda} = -\int_{x_\circ}^{x_\circ + l} dx, \qquad \text{and therefore}$$

$$(1) \qquad I'_\lambda = I_\lambda \varepsilon^{-\kappa_\lambda l}.$$

k_λ depends upon the wave-length of the light and upon the nature of the absorbing medium at the time of transmission and it is called the "absorption constant."

Replacing the constant $\varepsilon^{-\kappa_\lambda}$ by the single symbol a_λ we have

$$(2) \qquad I'_\lambda = I_\lambda \, a_\lambda^{l} .$$

Hagen has assigned to a_λ the name "absorption coefficient". Obviously, it is numerically equal to the fractional part of the light, of given wave-length, etc., transmitted by unit thickness of the medium. k_λ equals zero and hence a_λ becomes unity for the luminiferous ether. The equation for absorption in either form (1) or (2) is ordinarily known as Lambert's Law.

Historical and Experimental. The first theoretical law has a great deal of indirect evidence in its favor but very little direct experimental work has been carried out to test its validity. Bunsen* and Roscoe were the first to investigate this matter. They passed a beam of light through a cylinder containing chlorine gas and measured the intensities of the transmitted light corresponding to known intensities of the incident light. The range of incident intensities was very small and the limits of accuracy attainable differed by about two per cent, so that, although the authors found the law to be verified, this piece of work is of value and interest historically only.

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* R. Bunsen and H. Roscoe. 4 Abh. Pogg. Ann. 101 pp. 235-263, (1857).

The sole remaining investigation in this line, known to the writer, was carried out by Peddie* and published under the title, - "Proof that Density of Illumination does not affect Absorption". He says, "Professor Stokes suggested long ago a direct method of testing the point". "In his method the light is reflected at nearly perpendicular incidence from the surface of glass, and two equal portions of the absorbing medium are used - one being placed in the course of one half of the incident light, the other in the course of the other half after reflection". "Assuming that reflection is not affected by intensity we thus get a direct test of the question". "The author has used diverging light passing through two double-image prisms, a plate of quartz being interposed between them, and a lens being used for the purpose of proper definition". "By rotation of one diprism, and by varying the thickness of the quartz, we can match closely any colour of the absorbing medium , and also get the complementary colour". "One portion of the absorbing medium is inserted in the course of one ray, the other in the course of the similarly coloured ray, but at a different distance from the point of divergence". "Surface-

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* Brit. Assoc. Report for 1892, p. 661.

coloured glass was used in the experiments described". "No difference of absorption was evident, although the intensity varied from one to 1,000, and a change of intensity alone (unaided by colour comparison) of one part in 100 could be detected."

Lambert's Law as expressed by equation (2) has received more direct experimental verification than hypothesis I).

Bernard (a) studied the absorption produced by various thicknesses of glass, potassium dichromate and copper sulphate. He used colored glasses to render the incident light less non-homogeneous than it would otherwise have been.

Beer (b) considered the absorption to which aqueous solutions of copper sulphate, copper acetate and potassium ferrocyanide gave rise. Red glass was used by him to diminish the heterogeneity of the incident light.

Hagen (c) tested the law with a crystal of potassium ferricyanide by decreasing the thickness of the plate and determining the coefficient of absorption for the successive thicknesses.

Bottomley (d) devised his experiments in such a way that

(a). F. Bernard. Ann. chim. et phys. (3), 35 pp.385-438,(1852).
(b). A. Beer. Pogg. Ann. LXXXVI pp.78-88, (1852).
(c). O. Hagen. Pogg. Ann. CVI pp.33-55,(1859).
(d). J. Bottomley. Chem. News, 42 pp.56-58,(1880); also Mem. Manchester Lit. and Phil. Soc. (3), 7 pp. 176-186,(1882).

white light could be used as the incident radiation. When and only when the absorption coefficient is independent of the wave-lengths in a chosen region of the spectrum can Lambert's Law hold for this region. Therefore he made up a solution which approximated to the requirement of having its absorption coefficient independent of the wave-lengths occurring in the visible spectrum. This solution consisted of suitable masses of cobalt and nickel salts dissolved in water. Without entering into further details, it suffices to state that Bottomley conducted his experiments in such a manner as to produce the same intensity in the light emergent from two columns of the same solution but of different lengths. Preserving the definitions of the symbols in equation (2) we have $I' = I_1 a^{l_1} = I_2 \, a^{l_2}$ where the subscript λ has been omitted because of the nature of the absorbing medium. The result of a second similar observation would be embodied in the relation $I'' = I_3 a^{l_3} = I_4 a^{l_4}$. Bottomley kept his sources of light as nearly constant as possible, and even if they varied from one observation to the next, of a complete set, no harm could accrue because his two sources depended on a third single source in such a way as only to admit of proportional variations, i. e., the sources fulfilled the condition $I_1 : I_2 = I_3 : I_4$.

Therefore $\frac{I_1}{I_2} = \frac{I_3}{I_4} = \frac{a^{l_2}}{a^{l_1}} = \frac{a^{l_4}}{a^{l_3}}$ or $l_1 + l_4 = l_2 + l_3$. Bottomley obtained the numbers in the accompanying table.

$l_1 + l_4$	$l_2 + l_3$
25.3	24.93
28.4	27.4
28.45	28.76
29.7	27.8
31.95	30.35

Camichel (e) worked with thin layers of liquid bromine. He concludes;"The absorption of light in thin layers of bromine follows then the exponential law (in my experiments, the thicknesses used have varied between 0.5 and 60 wave lengths of sodium)."

The only direct observations which are not in agreement with Lambert's Law were made by Ångström and Königsberger, who worked, in the infra-red, respectively with gases and with doubly-refracting crystalline media. The errors of observation, however, were more than great enough to account for the deviations from Lambert's Law.

On the other hand, all the numerous theoretical deductions which have been made from Lambert's Law and which

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(e).C. Camichel. C.R. 117 pp. 307-309, (1893).

have been thoroughly tested experimentally, with comparatively modern apparatus and methods, confirm the law without exception. When apparent deviations have arisen they have invariably been shown to be due to some fault in the argument which involved Lambert's Law as a premise. For illustration, the ideas underlying this law have very frequently been tested by observations based on Beer's Law, and this last law has often been used in making calculations from observational data to which it is not even supposed to apply. Consequently, we may conclude that Lambert's Law is a correct metrical expression of the relations between the quantities with which it deals.

In addition to the study, outlined above, of the relationship of absorption of light to intensity and length of path traversed, a very large number of important theoretical and practical questions have been suggested, discussed and investigated, to a greater or less extent. The most significant of these deal with the following subjects.

The detailed, mechanical conception of the ultimate nature of absorption, as to interference, resonance, and so forth. All questions relating to the disappearance of

energy from light of a given wave-length and its subsequent manifestation in some other form or associated with light of some other wave-length, e.g., thermal actions, photographic phenomena, decomposition of non-silver salts, fluorescence, phosphorescence, etc. All causes which produce changes in the absorption spectra of given substances, such as; the effect of concentration, (Beer's Law for liquid solutions when the numbers but no characteristics of the molecules are changed); the influence of "colorless" solvents, (Kundt's Rule); electrolytic dissociation; hydrolysis; the mutual influence of two or more solvents, (Melde's experiments); variation of absorption with temperature; the effects of pressure and temperature in gases; changes of state, solids, liquids and gases; the laws of absorption of different salts of the same base; the connection between the absorption and chemical constitution of organic compounds, (Hartley's investigations); etc.

We shall have practically nothing more to say about these matters for two reasons, first, because they have little direct bearing upon the experimental results recorded in this research and second, because all the questions in the field of investigation mentioned above, together with a very great number of allied ramifications of

of the subject, are exhaustively treated in an invaluable volume which has just appeared. It is the third volume of "Handbuch der Spectroscopie" by H. Kayser; Leipzig, S. Hirzel 1905.*

OBJECT OF THE PRESENT INVESTIGATION.

If we look over the literature of the subject of absorption of light we fail to find a collection of absorption spectra presented in such a manner as to enable the observer to select at a glance a substance which produces either general or selective absorption in any specified part of the visible or ultra-violet spectrum. The wave-lengths of the absorption bands and other characteristics of the absorption exhibited by innumerable natural and artificial compounds and mixtures, both inorganic and organic, may be found in a great many books, journals, memoirs and dissertations. If all of these results were reproduced and catalogued in one volume they would not satisfactorily fulfil the requirements just mentioned because the different experimenters have had various objects in view and hence they have worked in various and limited parts of the spectrum, have used different numerical dis-

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* Except in so far as Peddie's work is concerned, there is much similarity between the preceding prefatory remarks and the corresponding sections in Kayser's third volume, nevertheless the above mentioned facts were presented in substance before the Physical Seminary of the Johns Hopkins University, by the present writer, on Nov. 23, 1903, long before the third volume was published.

persions, have employed optical systems of unlike dispersion curves, have not made it possible even to reduce their results to graphical form much less to a common basis of wave-lengths and normal dispersion, etc. The nearest approach to a work of the kind under consideration is made by the publications of J. Formánek, especially the two volumes entitled respectively "Die Qualitative Spectralanalyse anorganischer Körper" and "Spektralanalytischer Nachweis künstlicher organischer Farbstoffe;" Berlin, 1900. Formánek's investigations are very extensive and complete from the point of view explicitly stated in the preface to the last named volume. It was his aim to develop a practical spectroscopic method of procedure by which any given organic coloring matter could be unambiguously identified. He says;"Das Princip des hier beschreibenen neuen Verfahrens beruht auf der Kombination der spektralanalytischen Beobachtung und der chemischen Untersuchung; dieses Verfahren liefert nicht nur sichere Resultate, sondern sein Vortheil liegt auch darin, dass man mit Hilfe desselben alle einzelnen Farbstoffe von einander unterscheiden kann." Formánek, in order to obtain his results, varied the concentrations of his solutions until each absorption band

of a given substance became in succession as well-defined as possible so that the wave-lengths of their maxima might be read off with precision. This method is preëminently adapted to locating maxima but it gives very little, if any, information relative to the absorption between and beyond the maxima, for bodies exhibiting marked selective absorption, and it tells even less about substances presenting weak, general absorption. Another important respect in which Formánek's diagrams fail to give the data required by the first sentence of this section is that he confined his measurements to eye observations, unaided by fluorescent screens, and hence he omitted the entire ultra-violet region. In fact, his wave-lengths have the limits $420\mu\mu$ and $741\mu\mu$, i. e., from "above" the G line to a little "below" the *a* line. Formánek used a prism spectroscope to the dispersion of which he gives no clue.

To fill in this gap in the then existing collections of absorption spectra the present research was begun, at the suggestion of Professor R. W. Wood, in the spring of 1903. Its chief object is *to furnish graphical representations, on a normal scale of wave-lengths, of the absorption spec-*

tra, both in the visible and in the ultra-violet regions, of a reasonably large number of compounds.

The most obvious use to which such a collection can be put is the production of color-screens either for photographic work or for removing higher orders of spectra from the first order, in the case of diffraction gratings. It also makes possible the selection of such solutions as will transmit relatively narrow, and hence roughly monochromatic, regions of the spectrum. Such solutions are often convenient substitutes for somewhat elaborate pieces of apparatus which first disperse the light by a prism (or grating) and then permit any desired portion of the resulting spectrum alone to continue uninterrupted by means of a suitable slit and screens. Other directions in which the data given below may be of practical value need not be pointed out here.

Before entering upon the details of this work it was hoped that some general results, of a more or less theoretical bearing, might perhaps be obtained. The complicated chemical constitution of most of the absorbing media studied soon dashed this hope completely. Certain relations between chemical constitution and absorption, as observed and discussed by W. N. Hartley, are readily

seen to be substantiated by the curves at the end of this dissertation. The same is true concerning a very recent paper by Krüss*.

SELECTION OF MATERIAL, APPARATUS, etc.

That a great deal of time was consumed in constructing apparatus and in performing preliminary experiments is shown by the fact that, although the investigation was entered upon in the spring of 1903, as stated before, it was not until July 25, 1904 that the first wide negative was obtained.

Absorbing Media. Because of their great variety, strong selective absorption, and general interest, aniline dyes and their related organic compounds were selected as best suited for the study contemplated. For obvious reasons, the solvent was in most cases distilled water.

For the purposes in view and, in fact, for other spectroscopic work, the following things would be, as is very well known, of inestimable value.

(a). A dispersing system possessing,
    (1) exactly "normal" dispersion,
    (2) tolerably large resolving power,
    (3) the ability to reflect or transmit non-selectively nearly all the energy incident upon it,
    (4) no overlapping spectra or diffused light,
    (5) no astigmatism.

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* P. Krüss. "Uber die Absorption organischer Farbstoffe im Ultraviolett".
Ztschr. f. Physikalische Chemie. Band LI, Heft 3, March 17, 1905.

(b). A photographic emulsion equally sensitive for all wave-lengths from, say, 1μ to 0.2μ, and of good keeping qualities before exposure and development.

(c). A source emitting a continuous spectrum of relatively large intensity in the ultra-violet as far as 0.2μ.

(d). A source possessing, in addition to the property just named, constant intensity for all wave-lengths emitted.

As might well have been prophesied, not one of these desiderata was obtained.

Dispersing System. In order to obtain reasonably normal spectra a spherical,concave, speculum grating, whose radius of curvature was 98.3 cms., was used. For the first order spectra and for short photographic exposures the astigmatism of the reflector did not produce deleterious effects. This was determined by actual measurements. The length of one line of the ruling was 1.96 cms., and the assemblage of lines covered 5.36 cms. The spectroscopic resolving power was 21,250, (2.125 in. with 10,000 lines per in.). The inconvenience of superposed higher orders will be mentioned later on. To obtain a general idea of the normality of the spectrograms and of the linear dispersion it may be stated that, by calcula-

tion, one millimeter the centre of which was at 214.7 $\mu\mu$, or 399.4 $\mu\mu$, or 656.3 $\mu\mu$ covered 25.77, 25.84 and 25.71 A.U. respectively, for the spectrum was designed to be normal at the air line 399.4 $\mu\mu$.

Photographic Material. Because of the short radius of curvature of the focal surface (about 49 cms.) celluloid films were employed in most cases. The films used throughout were M.A. Seed's "L-ortho cut negative films", size 5" x 7". The emulsion is by no means equally sensitive over the field of wave-lengths studied, i. e., from 0.2 μ to 0.63 μ. The chief maximum of sensitiveness is in the yellow, about 0.56 μ. A much weaker maximum is near 0.49 μ. The middle of the less sensitive intervening region is very roughly 0.52 μ. For the short exposures given throughout, these films are not appreciably influenced by wave-lengths longer than about 0.61 μ. The resultant effect of the Nernst glower and the Seed emulsion is best understood by referring to plate 24 fig 92, for which the times of exposure were , in order, 2 secs., 5 secs., 15 secs., 30 secs., 1 min., 2 mins., and 3 mins. Various schemes to make the resultant action more uniform

were tried and other makes of films were tested but no improvement on the simple combination of the Seed emulsion and the Nernst glower resulted, therefore they were used almost exclusively. The Seed films are good in the ultra-violet because with an exposure of five minutes the aluminium line at 185 $\mu\mu$ was clearly recorded. To see if appreciable shifts in the apparent positions of the absorption bands were produced by the yellow maximum and the green minimum of the Seed films, negatives of the same absorbing medium, under exactly the same conditions, were taken on several different makes of films and plates which did not exhibit maxima and minima of sensitiveness for the same wave-lengths. Also, other and independent tests of this possible source of error were made. The conclusion was that no noticeable displacements of the bands were caused. However, in the cases of brown and other visibly colored solutions, exhibiting weak, general absorption, the observer of the appended positives must be careful to distinguish between true absorption and the spurious effects in the vicinity of 0.52 μ. A differentiating criterion which is usually sufficient is that the pseudo bands do not vary in intensity across the width of the spectrogram whereas the intensity of true bands

increases from the comparison spectrum to the opposite edge.

In photographing bands in the orange and red, Cramer "Trichromatic" plates were found to be the best and hence they were used. The plates being plane they had to occupy a mean position with respect to the focal surface of the grating. Since only a comparatively small region of wave-lengths was recorded in this manner, no measurable errors were introduced. In fact, in the region considered, the second order ultra-violet of a discontinuous spectrum taken on a film and on a plate could be superposed line for line.

The developer used was a simple hydrochinone solution made up according to Jewell's formula.*

Sources of Light. For wave-lengths from "above" 0.65μ to "below" 0.326μ, and for exposures of about one minute, the Nernst glower was found to be the most satisfactory. Prevailing circumstances made desirable the use of 104 volt glowers on a circuit carrying about 133 cycles. The emissivity of the Nernst lamp varies so very greatly with the e.m.f. impressed upon its terminals that it was obligatory to keep in series with the glower a Thomson A.C.

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* L. E. Jewell. Astrophys. Jour. v. 11, 1900 pp. 240-243.

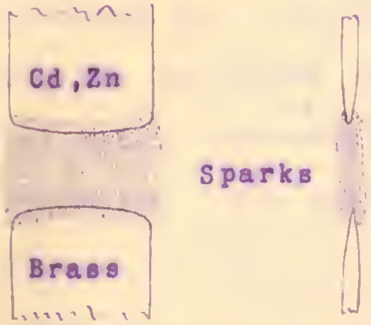
ammeter having a range from zero to two amperes and graduated directly to 0.02 ampere. Fluctuations of more than 0.02 ampere invariably resulted in a spoiled photograph consequently boxes containing variable metallic resistance were maintained in series with the ammeter and thus, in spite of large changes in the load on the dynamo, due to other experimental circuits, it was possible to prevent the effective current in the filament from changing by more than 0.01 ampere. The current was usually 0.8 ampere or a little less. The ammeter was appreciably more sensitive to small changes in the terminal voltage than a comparably graduated Thomson A.C. voltmeter because the current shunted through the voltmeter was not negligible in comparison with the current which fed the glower. Among other sources the electric arc was given a fair trial and discarded for two reasons, first, because of the intensity of the carbon and cyan bands, and second, because of the inconveniences resulting from its unsteadiness and great emission of heat.

For wave-lengths between the strong ultra-violet of the Nernst glower and 0.2μ a spark discharge in air of about one centimetre length was used. In obtaining the greater

number of the negatives one electrode was composed of an alloy of equal parts by weight of cadmium and zinc and the other was made of sheet brass. The alloy wore away so rapidly that the brass electrode was employed to reduce the mechanical labor attendant upon sharpening the terminals. The electrodes were given a form apparently not described before. As is very well known, many spectral lines, both weak and strong, produced by sparks between metallic surfaces extend only a short distance beyond the metal and hence do not offer a continuous source of light across the entire spark gap. In order to obtain a background of uniform intensity from edge to edge of the negatives it was necessary to use some scheme to nullify the effects of the non-uniformity of emission in the spark. One way of accomplishing this is to rapidly translate the electrodes (maintained at a fixed distance apart) back and forth parallel to the length of the slit of the spectrograph by some mechanical device.

The reciprocating action associated with this plan shakes the camera and grating to such an extent as to demand greater rigidity in the apparatus than is usually possessed by it. Therefore the electrodes were made in the shape of wedges or chisels with the sharp edges parallel

to the slit. The well known distribution of a rapidly alternating current in a conductor necessitated curving the edges of the electrodes, as is shown in the accompanying diagram which is of natural size. Due to the tearing away of the metal, and to various other causes, the innumerable thread-like sparks changed the positions of their ends so rapidly that the integrating action of the photographic film recorded a perfectly uniform negative for exposures of fifteen seconds or more. The exposures generally lasted seventy-five seconds. The electrodes had to be kept sharp and smooth for, when this was neglected, the elementary sparks persisted much longer in one position than in another and consequently caused streaks of varying intensity to run along the negatives parallel to their length, as can be seen in some of the positives reproduced in the appended plates, e.g., figure 91, plate 24.



Flat and edge views.

The current for the spark was obtained in the following manner. An alternating e.m.f. of about 106 volts (133

cycles) was impressed on the terminals of an induction coil of unknown ratio of turns. Eight or nine amperes commonly flowed in the primary. The interrupter of the coil was thrown out of circuit and the coil therefore performed the functions of a transformer. In parallel with the secondary was placed a Leyden jar about 18 in. high and of unmeasured capacity. No auxiliary spark was introduced. The system could spark about 2.5 cms. in air between metallic points.

The great intensity of some of the lines characteristic of all the common metals tried (Al, Cd, Cu, Fe, Pb, Zn, etc.) made these metals undersirable for the present work. Cadmium and zinc were selected only because of the strong continuous background to which they give rise. Figures 88, 89, 90 of plate 23 are at least suggestive. For figure 88 the spark passed for fifteen seconds between lumps of pure metallic uranium.* The comparison spectrum is a zinc exposure of twenty seconds. Figure 89 was the result for thirty seconds with commercial pitchblende lumps. When (other) pitchblende electrodes were oscillated parallel to the slit for two minutes the negative producod is copied in figure 90 . Uranium its salts or its earths

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* See also H. Kayser. "Handbuch der Spectroscopie" v.III p. 64.

were not used in this work because they are unmanageable. Naturally the pure metal burns to oxide at once; pitchblende cannot be worked into a suitable shape (at least, for such specimens as the writer has been able to obtain); and, pitchblende is so very heterogeneous that the position of the spark can not be depended upon for an instant. To have employed a neutral atmosphere in conjunction with a reciprocating mechanism would have consumed, obviously, too much time and would have demanded too complicated, cumbersome and inconvenient an assemblage of apparatus.

The Cell. In order to show the variations in the absorption spectrum of a given substance when the thickness of the absorbing layer changed linearly, a wedge-shaped cell was constructed. Vessels made on this principle have been designed and used often before, notably by Ångström, Gladstone, Govi, Gibbs, Tumlirz, Hodgkinson, F. Melde, Hartley, and others.* Nevertheless, because the precise form of the cell is supposedly new and certainly useful it may not be superfluous to enter into a detailed description of it here. This little piece of apparatus was designed so that the relative positions of the quartz surfaces through which the light entered into and emerged from the absorbing

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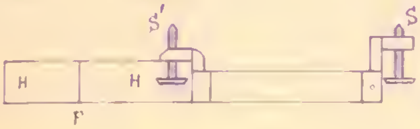
* Loc. cit. pp. 58,59.

liquid could be varied at will, within certain limits. In other words, matters were so arranged that the liquid could be in the form either of a wedge, of variable angle, with zero thickness at the refracting edge, or of a prism of variable angle and non-zero depth throughout, or of a plane parallel layer of changeable thickness. To satisfy these conditions it was convenient to rely upon the attraction of the earth to preserve certain parts of the cell in mutual contact. This in turn necessitated both the horizontal position of the bottom of the cell and, (because it was desirable to reduce the number of reflecting surfaces to a minimum), the vertical type of speculum spectrograph.

The cell comprised five separable parts, as follows; (1) a brass framework upon which the other parts rested; (2) a transparent tray, without a lid, which confined the liquid in proper bounds; (3) a transparent, box-like system which gave the upper surface of the liquid the desired position; (4) a vulcanite framework to hold the last mentioned box in place; and, (5) four mahogany pins or pegs to fasten the box to its framework. A photograph

of the parts of the cell, seven-tenths natural size, is given in plate 24 figure 93.

(1).



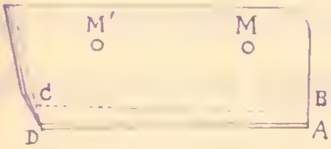
/2 nat. size.

(1). A side view of this framework is presented in diagram (1). There were three micrometer screws all of the same pitch, viz; 1 turn = $\frac{1}{48}$ in. = 0.053 cm. The heads of the screws were graduated, on their upper surfaces, in ten equal parts. The screw s was in the medial plane of the cell while the remaining screws, (s' only is shown), were at the other end of the system, were equidistant from this plane, and were as far apart as possible. The micrometer screws called for vertical scales on the adjacent brass-work to count whole turns. The handle is denoted by HH. A black fiducial mark, F, on a white ground enabled the experimenter to tell what position the cell occupied with reference to the length of the slit of the spectrograph. The lower end of F moved over a scale parallel to the slit and in the plane of the latter's jaws.

The flange at the bottom of the framework was made of brass 0.014 cm. thick so that the absorbing medium might be as near the slit as possible.

(2). An accurately ground plane-parallel plate of quartz 40 mms. long, 18.5 mms. wide and 2 mms. thick had cemented to its periphery four rectangular sheets of thin glass 8 mms. high. Hence, the greatest depth of liquid which could be studied by the aid of this cell was 6 mms.

(2).



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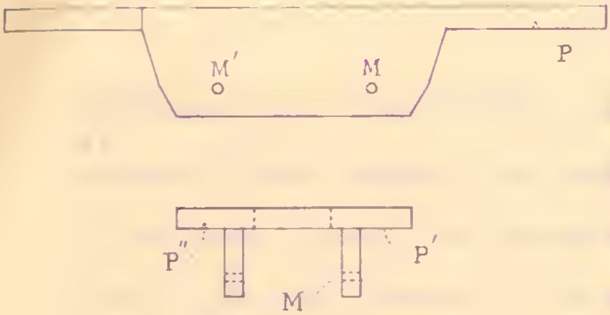
(3). In diagram (2), A,B,C and D designate the vertices of the section of a quartz plate, made by a plane perpendicular to the plane the trace of which is the line AD. AB was 2 mms., AD was 34.8 mms., and the angle between the planes of AD and BC was fifty-five minutes of arc. The horizontal width of the wedge was 10 mms. Glass walls surrounded three sides of the wedge, as the outline indicates. The reason for using the wedge was to counteract the deviation and dispersion produced by the solution in the cell. The angle of the liquid wedge could be varied until the deviation effected by the quartz wedge nullified the average action of the absorbing solution. At first it was supposed that with liquid wedges of fifteen or so minutes of arc a plane-

parallel quartz plate could be used successfully instead of the quartz wedge. This was true for some dyes but for concentrated solutions of certain other dyes (notably the sodium salt of p-methoxy-toluene-azo-β-naphthol-di-sulphonic acid) some compensating system was absolutely necessary. Finally, the quartz wedge was made with the utmost care by an expert optician, special pains being taken to have the edge through D, perpendicular to the plane ABCD, as sharply defined as possible, and the surfaces whose traces are denoted by AD and BC were accurately plane.

(3).



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(4). Figure (3) presents a side view and an end view of the vulcanite frame into which the quasi-box just described fitted. This frame was shaped out of a single block of vulcanite, for, experience showed that, a cemented system of several pieces did not last long, also a dielectric was needed to keep the sparks from jumping to the screws. P indicates a little depression which fitted over the point of the screw s. P' designates the end of a straight line along which the rounded extremity of the screw s' slid.

P" is the cross-section of a shallow, V-shaped groove along which the pointed end of the third screw, s", likewise slid. The perforations M, M' etc., correspond to each other and to the associated wooden pegs mentioned above as (5).

(4).

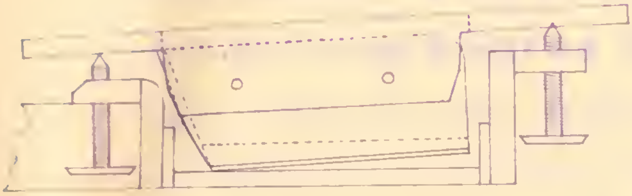


Diagram (4) is an unconventional sketch of the cell when completely assembled.

A cell of the construction just described is very well suited to the study of thin layers of solutions in solvents of relatively high boiling points such as water and amyl alcohol, but, unless enclosed in some suitable vessel, it is not applicable to solvents of lower boiling points like ethyl alcohol, ether, chloroform, etc.

Cements. A few words concerning cements may not be superfluous because a great many receipts were tried and only a very few were considered satisfactory. In the first place, no single cement was found which satisfied the following three necessary conditions, (a) of being unaffected by hot or cold water, (b) of being insoluble in the alcohols,

ether, chloroform, carbon bisulphide, etc., (c) of drying or setting in three or four days, at most.

The plan used by Professor H. N. Morse in waterproofing cells for the study of osmotic pressure gave the best results and hence it was followed in fastening together the quartz and glass parts of the cell described in the last section. These parts were first fastened together with Khotinsky cement in the usual way, that is, by heating them in an air bath, to any convenient temperature above the melting point of this cement, and by heating a stick of the adhesive mixture in a Bunsen flame and then applying it to the surfaces of the hot quartz and glass. Since this resinous cement is soluble in ethyl and amyl alcohol and other solvents, and because it is attacked by various liquids, such as an aqueous solution of potassium permanganate, it was necessary to coat the exposed surfaces of the cement with something which was chemically inert towards the solutions to be studied. Such a substance is a solution of rubber in carbon bisulphide. This solution was made and used as follows. From an adequate length of black, soft, rubber connecting-tubing segments about two centimeters long were cut and heated in an evaporating dish over a Bunsen flame until the sections fused, ran

together and formed a very sticky, viscous liquid. (A single long piece of tubing does not liquefy at all satisfactorily). The liquid state persisted after the contents of the evaporating dish had been allowed to cool down to about room temperature. Carbon bisulphide was next poured into the dish and the contents of the latter were stirred until a homogeneous solution obtained.

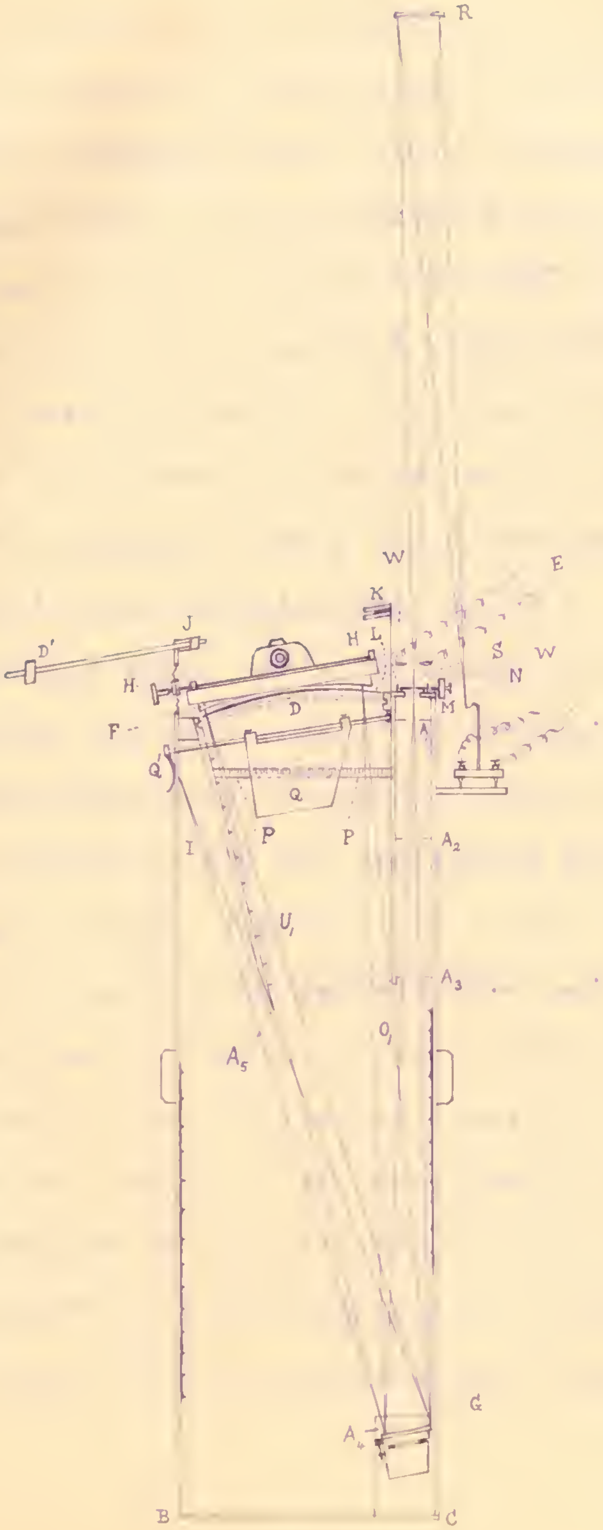
The relative proportions of the carbon bisulphide and rubber used were immaterial and were determined by convenience only. The solution can be retained indefinitely in a tightly stoppered bottle and used whenever needed. A thin layer of the solution was painted over the Khotinsky cement, after which the quartz-glass system was heated in an air bath at about 100° C. until the layer became dry and hard, and was no longer sticky. (Of course, during the first part of the process the transparent elements of the cell had to fit over a suitable wooden "form" because Khotinsky cement softens too much at 100°C. to maintain objects in their proper relative positions.) After this another thin coat of the rubber solution was applied and the heating continued. This succession of operations was repeated until a thick, hard, dark-brown covering for

the joints was obtained. It then made little difference whether the original cement were present or not because the hard-rubber held the quartz and glass together very satisfactorily indeed. The total time required for heating the successive layers of rubber was about sixty hours.

A cement which dissolves readily in water and in acetic acid but which is not affected by ethyl alcohol, amyl alcohol, carbon bisulphide, glycerine, chlorform, ether, benzol , nitrobenzol, aniline oil B, benzaldehyde, toluol, etc. is made by dissolving two pounds of pure gelatin in one quart of water and adding to the resulting solution seven ounces of nitric acid, (sp. gr. 1.35-1.42). The final solution is colorless and when applied in this layers dries in a day or so. It is called Dumoulin's liquid glue.

The Spectrograph.

The essential parts of a vertical section of the spectrograph are outlined in diagram (5). They may be tersely described, with the aid of symbols, as follows. In the first place, every element of the system was adjustable in every respect. Light from the Nernst filament, N, was focused by the concave speculum mirror, R, on the slit, S, whence it continued to the grating G, from which a portion



1/10 nat. size.

of it was dispersed in the direction of the sensitized film, F. The adjustable support of the mirror, which was rigidly attached to the main body of the spectrograph, is not outlined in the diagram. The distances of the middle of the slit to the centres of the mirror and grating were respectively about 89.5 cms. and 97.1 cms. The electrodes, E,

were always at the distance of 4.2 cms. above the slit and they did not interfere with the passage of the light from the reflector to the slit. No lenses or other reflectors were used. The micrometer head at M indicated the separation of the slit-jaws. W shows the ways or guides between which the cell was slid along over the slit. QQ' denotes a screen system such that when Q was vertical the passage of light from the grating to the camera was not interfered with, whereas when Q was horizontal only ultra-violet light of shorter wave-lengths than 0.4 μ could reach the photographic film. PP is an horizontal platform with a scale along its front edge. By sliding projecting, horizontal, opaque screens of various widths along this platform it was possible to cut out completely any region or regions of wave-lengths desired. In making certain tests, the platform and sliding screens were very convenient. L is the section of a thin, black, metal shutter capable of translation in an horizontal direction and hence at right angles to the length of the photographic films; in other words, parallel to the slit and to the rulings of the grating. A number of long, rectangular, suitably spaced and proportioned slots or openings were present in this screen so that

strips of different widths of the films or plates could be exposed to the light from the grating without causing any displacement of the sensitized surfaces with reference to the grating and slit. This was necessary for impressing comparison spectra, etc. HH suggest the rack and pinion system by the aid of which the films could have unexposed portions brought successively opposite to some selected opening in the slide-screen L. D and D' denote two of the four doors which gave access to the interior of the spectrograph and which made it possible to close up the camera light-tight while making various adjustments with the rest of the system. The camera was made so that, when it contained neither a film nor a plate, it was possible for the experimenter to look directly at the grating and to make observations with the assistance of an eye-piece. Certain black-on-white scales and ruby glass windows enabled the experimenter to know the precise relative positions of the various accessories on the interior of the spectrograph when the entire system was shut up and exposures were being made. Numerous dull black diaphragms and screens, (A_1, A_2, A_3, A_4, A_5, etc.), took care of the unusable light of the central image, I, and of various spectra. U_1 and O_1 give the extreme rays of so much of the first order spectrum as was

studied, that is, U_1 and O_1 correspond respectively to about 0.20μ and 0.63μ. Naturally, the spectrograph was dull black, both inside and out, and contained plaited black velvet in appropriate places. A general idea of the size of the apparatus may be derived from the following dimensions; - from R to the plane of BC = 198.5 cms., BC = 34.5 cms., the bottom edge perpendicular to BC = 27.5 cms., BJ = 116 cms., and JK = 29 cms.

Manner of Experimenting.

Solutions. A small, know mass of a selected dye was carefully"weighed out" on a chemical balance, and put at the bottom of a medium-sized test-tube. Then distilled water was run from a burette into the test-tube, and the latter shaken up from time to time, etc., until the resulting solution appeared to have the proper concentration. As would be expected, practice produced skill in judging absorption of visible light, but to get the right concentration with respect to ultra-violet light was not always so easy. The greatest error in measuring the solvents was about 0.2 per cent. Since the concentrations are only intended to serve as general guides to an understanding of the spec-

trograms, a higher degree of accuracy would have been superfluous. Neither was there any reason, in general, for noting the volume of solution which contained a known number of grams of pure solvend, in other words, changes in volume due to the processes of solution were not regarded.

Adjustment of the Cell. Especial care was taken to remove all coloring matter from the cell before introducing another solution into it. (Dust caused more trouble than anything else). After cleaning the quartz and glass elements of the cell the various parts of the latter were assembled and, when a prism of liquid was to be studied, the micrometer screws regulated in the following manner. All the screws were turned down so as not to touch the vulcanite framework, and thus to cause the quartz wedge to rest on the quartz plate. Then the screw s had its point elevated again and again until it just touched the deepest part of the depression P. (See diagrams (1), (2), (3) and (4).) This condition was attained by gently rocking the system around the edge D of the quartz wedge, somewhat after the fashion of experimenting with certain types of spherometers. Thus the zero position of the cell was determined, (before each experiment, of course). Next, guided

by the circular and plane scales, the observer turned up the screw S until the desired angle, between the wedge and plate,was known to obtain. After this, the screw corresponding to S' was turned up until its tip projected far enough into the groove P" to prevent the quartz wedge and its accessories from sliding over the quartz plate around the point S as pivot, but yet not far enough to raise the vulcanite frame the least bit. Finally, a small amount of the solution was poured into the cell and the latter was then placed on the very thin brass sheet which rested upon and protected the jaws of the slit.

As soon as the cell was placed over the slit and the glower had been lighted the cell was moved forward and backward, parallel to the slit, while one edge of the field of view was examined with an eye-piece, until a position of the cell was obtained for which the light passing through the quartz wedge at its refracting edge,(D of diagram (2)) illuminated the very limit of the field of view as seen through the chosen slot of the shutter,(L of diagram (5)). The position of the mark on the handle of the cell,(F of diagram (1)), with respect to the horizontal scale in the plane of the slit-jaws, was then read off. If the cell were then moved, ever so little, in one direction

the width of the brightly illuminated field could be seen to be less than the opening in the shutter; whereas, if the cell were translated in the opposite sense no increase in the width of the illuminated field occurred. At this opportunity, eye-observations of the visible absorption bands were always made and recorded.

When the concentration of the liquid in the cell was much too great or far too small this instrument had to be cleansed and filled with a solution of more suitable absorbing power, obviously, but when the concentration was not too remote from the best value the effective depth of the cell was varied until the desired state of affairs obtained.

All three screws were raised and regulated in an obvious manner when prisms of liquid having nowhere infinitesimal thickness were wanted. When layers of liquid of uniform depth were studied a system much like that shown in diagram (2), but which had for bottom a plane-parallel plate of left-handed quartz 2mms. thick, was substituted for the quartz-wedge system.

Calibration of the Cell. The diedral angles formed by the cell were calculated from the dimensions of the

instrument.*

Let K symbolize the length of the perpendicular dropped from the deepest point of the depression P upon the lower plane, (AD continued), of the quartz wedge, when systems (3) and (4) were fastened rigidly together. Let l denote the shortest distance from the foot of the perpendicular just defined to the diffracting edge of the prism, that is, to the line which, in diagram (2), passes through D at right angles to the plane of the paper. Let α be the angle between the quartz planes whose line of contact has just been described. Let x stand for the number of centimeters through which the screw point, S, has been raised from the initial, zero position. x and α equal zero simultaneously with the extended contact of the quartz surfaces. The construction of the cell justified the assumption that the axis of the screw S was normal to the horizontal planes of the quartz plate belonging to system (2).

It follows immediately that $l \sin \alpha + K \cos \alpha - (K+x)=0$.

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* The cell was carefully calibrated by direct goniometrical measurements with a spectrometer and the values obtained for the angles in this manner agreed very well with the numbers calculated from the formulae.

This equation assumes the forms $\tan 1/2\,\alpha = \frac{\ell - \sqrt{\ell^2 - x(x+2K)}}{x + 2K}$ and $\tan 1/2\,\alpha = \frac{x}{2\ell} + \left(\frac{x}{2\ell}\right)^3 + \frac{x^2 K}{4\ell^3} + \text{etc.}$ For small angles, and for the degree of accuracy obtainable in measuring K and ℓ, ($K = 1.60$ cms., and $\ell = 4.70$ cms., for one system), the dragging of the wedge over the lower plate, while S is being elevated, can be neglected and there results the much simpler condition $x = \ell \sin \alpha$.* Of course, for very small angles $\alpha = x/\ell$, simply.

Exposures and Spectrograms. The majority of the spectrograms consist of three distinct photographs taken side by side and as close together as possible. (See the plates). The width of each photograph was practically the same as the width of the opening in the shutter L. Numerous trials showed that this field of view was completely filled with light, with no overlapping on the grating-side of the opaque portions of the shutter, when the length of the slit was diaphragmed down to 10.5 mms. Consequently, the slit was limited to a length of a very little more than this number and the cell was moved along exactly 10.5 mms between the taking of two adjacent photographic strips on the same film. By this means, the thickness of absorbing liquid through which the light passed to the very edge of one

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* For $\alpha = 0.5, 1, 1.5, 2$ this formula yields respectively $x = 0.77, 1.54, 2.31, 3.08$ turns of the screw.

photographic strip was equal to the thickness subsequently traversed by the light which recorded itself at the contiguous edge of the adjacent strip. Of course, the best appearing records were obtained when the film holder, actuated by the rack-and-pinion system, was moved, by an amount exactly equal to the width of the opening in the shutter*. A casual inspection of the positives reproduced in the appended plates shows that mechanical shifts, in wave-lengths, of the strips on one complete spectrogram, with reference to one another, exist. This may mar the appearance of the photographs somewhat, but the ultra-violet spark lines show the magnitude of the displacements so that corrections can be made, and hence the ultimate scientific value of the results is not decreased.

The order of events in taking a complete negative of three strips was invariably as follows. The thickest layer of absorbing liquid was over the opening of the slit first, then the intermediate layer, and last of all, the thinnest layer which usually tapered to infinitesimal depth. This sequence enabled the comparison spectrum to be taken by moving the shutter, L, without jarring the film holder, so as to minimize the shifts of this spectrum

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* Save the grating, the mirror and the slit system, the entire spectrograph was designed and personally made by the writer, and because (mahogany) wood was used in the construction of the camera and because the work was not done by machinery, the photographic strips do not always match in position as well as could be desired.

relative to adjacent photographic strip. For negatives of more than three strips precisely the reverse succession was adopted because it was easier to commence with the cell in adjustment and then to raise the quartz wedge parallel to itself than to lower all three micrometer screws by the same number of turns until the quartz wedge just barely came into contact with the quartz bottom of the cell. With the screen Q horizontal the first exposure with the spark was taken. The screen was lowered and the second exposure was made, this time with the Nernst glower. These two exposures produced the first of the three photographic strips. Next the film-holder and cell were moved the proper distances, as explained above. The glower and spark exposures followed in the order named. After again moving the film-holder and cell the fifth and sixth exposures were produced by the spark and glower respectively. Finally the cell and diaphragm were removed from the slit, another opening in the shutter was adjusted before the film, and then the comparison spectrum was impressed. Almost always the glower exposures lasted 60 secs., the ultra-violet exposures 75 secs., and the comparison exposures consumed

35 secs. The width of the slit was always 0.008 cm. In any one complete spectrogram the exposures to the Nernst light were all equal to each other and those for the ultra-violet were related to one another in the same manner. Experience showed that the intervals 60 and 75 seconds were best suited to cause the overlapping ends of the photographic impressions to blend as if they had been produced simultaneously by light from a single source. With the longest exposures used, the light from the glower did not affect the films and plates for wave-lengths as short as 0.315 μ and since the field photographed did not comprise wave-lengths longer than 0.63 μ, there was no trouble produced by the ultra-violet of the second order. The screen Q took care of this matter so far as the spark exposures were concerned. Figure 60 plate 16 indicates how the processes just explained can be extended to negatives as wide as may be desirable and hence to as deep layers of absorbing liquid as may be wished.*

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* Of course, a cell deeper than 6 mms. would be necessary if the matter were pushed very far.

PART II.

DESCRIPTIVE TABLES.

RESULTS.

Interpretation of the Curves. If the distances from the edge of a positive which is adjacent to the comparison spectrum, and which therefore corresponds to zero depth of liquid in the cell, to arbitrary points on the boundary of a sharply defined absorption curve be called ordinates, and if wave-lengths be considered as abscissae, we may say that the absorption constants* associated with any two chosen wave-lengths are inversely proportional to the ordinates belonging to these wave-lengths. This statement involves certain assumptions, about emission curves and sensibility curves, a discussion of which will not be given here.

If the edge of an absorption band is a straight line at right angles to the length of the picture it means that the position of this side of the band will not appreciably change with wide variations in the concentration of the solution, in other words, the limit of absorption will remain at the same wave-length regardless of the concentration. This is roughly the case in figures 4 and 60 of plates I and XVI

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* K_λ of page 4 .

at the respective wave-lengths 0.29μ and 0.515μ. If this condition holds for all the bands of a given substance, which are within or near the confines of the visible spectrum, the color of the light transmitted by the solution will be the same no matter how much the concentration be varied.

When the boundary of an absorption band is a straight line inclined to the axis of wave-lengths it may be inferred that the limit of the band will be displaced in proportion to the change of concentration, and that the factor of proportionality depends upon the angle which the line makes with the axis of abscissae. This is exemplified in plate XX figure 77 by the portions of the band, at wave-length 0.47μ corresponding to the thicker layers of liquid.

In like manner, the general relation between the displacements of the limits of absorption and the associated changes in concentration may be easily inferred when the confines of the absorption bands are curved either convex or concave.

Explanation of the Tables.

Two plans suggest themselves for the sequence of the experimental data, viz. (a) to classify the material on the

basis of the characteristics of the absorption spectra, i.e. the succession, intensity, etc., of the bands and regions of absorption; (b) to arrange the results according to the chemical nature of the absorbing media. Because the first method conforms more clearly to the professed object of the present research than the second, every scheme consistent with it was tried which suggested itself. In fact, all the negatives were placed at one time upon a large, white area and various tentative classifications were attempted. The great number of combinations on the negatives of the effects of weak, general absorption with definite, intense bands, combined with more or less uncertainty as to the interpretation of the negatives in the region for which the source of the discontinuous spectrum had to be used, made it impossible to find a satisfactory permutation of the photographic records. Consequently the second plan suggested above was followed as closely as possible. The organic coloring matters succeed one another in the same order as is given to them in the English translation by A. G. Green of a book by G. Schultz and P. Julius entitled "A Systematic Survey of the Organic Colouring Matters". MacMillan & Co., London 1904. This connection between the contents of the volume just named and the ma-

terial recorded below has the advantage of making it easy to find out many things about the dyes which can not be appropriately given here, such as the names of their discoverers, their literature, patents, methods of preparation, behavior with various reagents, chemical constitution, etc.

The descriptive tables following this explanatory section present the experimental results in the following order;-

(1) The absorption of a small number of interesting intermediate products, so-called, arranged according to the alphabetical order of their names.

(2) The absorption of such dyes as were studied and were capable of identification with the dyes discussed in the aforesaid book by Schultz and Julius.

(3) The absorption of such dyes as were not unquestionably the same as any given in the reference volume. The accounts of these dyes follow the alphabetical order of their commercial names.

(4) The absorption of certain miscellaneous objects of more or less interest, in alphabetical order.

Whenever a number without qualification is given to a substance it refers to the present account, but when a number is quoted from the volume by Schultz and Julius attention

is called to the fact by the abbreviation S. and J.

In the brief account of any one substance the details are presented in the sequence explained by the following sentences.

1st. The arbitrary number of the substance in the present list is given.

2nd. The commercial name of each substance is recorded precisely as it was labelled by the firm which furnished the coloring matter. When two firms sent the same dye under the same or under different names the circumstance is explicitly presented.

3rd. Immediately after the commercial name that of the factory is given. The dyes were obtained from three sources. Both the Actiengesellschaft für Anilinfabrikation and Meister, Lucius & Brüning presented a large number of dyes of their manufacture to the Johns Hopkins University. The remaining dyes were purchased from the firm of Eimer & Amend, New York. The following abbreviations are used throughout.

(A.) Actiengesellschaft für Anilinfabrikation, Berlin (The Berlin Aniline Co.).

(A.A.C.) The Albany Aniline Color Works, Albany, N. Y.

(B.) Badische Anilin-und Sodafabrik, Ludwigshafen a./Rhein (The Baden Co.).

(By.) Farbenfabriken vorm. Fr. Bayer & Co., Elberfeld (The

(The Bayer Co.).

(C.) Leopold Cassella & Co., Frankfurt a./M.

(D.) Dahl & Co., Barmen.

(D.H.) L. Durand, Huguenin & Co., Basle and Hüningen.

(G.) J. R. Geigy, Basle.

(I.) Société pour l'Industrie Chimique (formerly Bindschedler & Busch), Basle.

(K.) Kalle & Co., Biebrich a./Rhein.

(M.) Farbwerke vorm. Meister, Lucius & Brüning, Höchst a./ Main (Meister, Lucius & Brüning, Limited).

(O.) K. Oehler, Offenbach a./ Main.

(P.) Société Anonyme des Matières Colorantes de St. Denis, Paris.

4th. The chemical name of the absorbing medium is given .

5th. Reference is made either to the figure (or figures) and plate which belong to the substance under discussion itself or to a figure which is very much like the spectrograms of the dye considered.

6th. When possible, the number of the dye or the page of the intermediate product, as found in the volume of Schultz and Julius, is recorded.

7th. The color and superficial character of the dry coloring matter is suggested.

8th. The color of the solution as observed in a test-tube is followed by the color in the cell. The change of color with thickness is often significant.

9th. Then follows the concentration in grams of dry solvend in a liter of solvent. The term "saturated" is to be understood in its general, practical sense and not in the almost unattainable, theoretical sense. Parenthetical, qualifying words, such as "(heated, filtered)", call attention to the fact that the substance does not dissolve readily in water, or that the solution contained gritty, foreign material, etc.

10th. Next is given the angle between the quartz plates forming the top and bottom of the various cells used. In the same line the numbers denote in order the minimum and maximum depths of solution through which the light passed before acting upon the outer limits of the negative. The intermediate thicknesses vary linearly, of course. The same angle is not always associated with the same maximum depth, even when the minimum thickness is unchanged, because several cells of different dimensions were employed.

11th. Finally, a brief account of the most noticeable characteristics of the absorption spectrum, between the limits 0.20 and 0.63, is furnished.

The results of eye-observations of the absorption spectra come first and serve as checks on the photographic records. The data obtained visually are qualitatively reliable for all strong bands between 0.40μ and 0.63. For cases of very weak, general absorption much less importance must be ascribed to the visual results because, unfortunately, the cells were not constructed so as to present side by side, in the field of views, two spectra, the one of the light after passing through the absorbing solution, the other of the unabsorbed light direct from the Nernst glower.

When the solution is fluorescent, or decomposes when ultra-violet light falls upon it, or possesses a characteristic odor, etc., the facts are noted. That the spectrograms are not distorted by the presence of fluorescent light, but give as true records of the absorption spectra of fluorescent compounds as they do for non-fluorescent solutions, was ascertained by direct experiments. (In par-

ticular, see the record for solution No. 107.)

Lastly the approximate wave-lengths of the maxima and minima of absorption, as obtained from the spectrograms, are given, beginning near 0.20 and continuing to .063 . When the wave-lengths of the "ends" of a region of absorption are given they obviously have significance only under the conditions of thickness of absorbing layer, of concentration, of length of photographic exposure, etc., which prevailed at the time when the spectrogram was taken. The maxima are not subject to the same limitations. The fact that the Seed films can produce spurious absorption bands in the green must be again emphasized. (See fig. 92 plate 24). When the end of the spectrogram, which marks the fading away of the sensitiveness of the emulsion from the yellow to the orange, is practically a straight line perpendicular to the length of the spectrogram it means that there is no appreciable general absorption in this locality, but when the limit just specified is approximately a right line inclined at an obtuse angle to the positive direction of the axis of wave-lengths it signifies that appreciable general absorption is present in this region. Figures 57a and 57b of plate 15, and also figures 47 and 48 of plate 12, contrast the apparent absorption as shown by a film in a region of wave-lengths for which the emulsion is only slightly sensitive with the true absorption as recorded by a plate possessing full sensitiveness to the same part of the spectrum.

INTERMEDIATE PRODUCTS.

1. Amidonaphtholdisulphonic Acid H. (M.)

Fig. 1, plate 1.

Pp. 57 and 58 S. and J.

Grayish white lumps.

In solution; brownish yellow; colorless.

Saturated.

Angle 27.'3 . Depth 0 to 0.25 mm.

No visible absorption. Intense blue fluorescence. Ultra violet absorption ends about 0.347μ.

2. β - Naphtholdisulphonic Acid G. (M.)

Figs. 2 and 3, plate 1.

P. 51 S. and J.

Pinkish white powder.

In solution; colorless.

Saturated.

Angle 27.'3. Depth 0 to 0.25 mm.

No visible absorption. Intense blue fluorescence. The absorption ends very definitely and follows approximately a straight line from 0.346 to 0.356 . Figure 3 shows the absorption exhibited by a solution made by diluting a certain volume of the saturated solution to eight times its original value.

3. *p* - Nitraniline. (Powder, "extra".) (M.)

P. 12 S. and J.

Lemon yellow powder.

In solution yellow; faint yellow.

Saturated.

Angle 37.'1. Depth 0 to 0.34 mm.

No visible absorption is produced by a column 6 cms. deep. The entire ultra violet absorption is weak. A region of slight absorption from 0.20 to 0.255 is followed by transparency as far as 0.34 . Faint absorption extends from 0.34 to 0.40 . From 0.40 to 0.63 no absorption is noticeable.

4. *O* - Nitrobenzaldehyde. (M.)

P. 61 S. and J.

White needles.

In solution; colorless.

Saturated.

Angle 31.'2. Depth 0. to 0.29 mm.

Extremely weak absorption from 0.20 to 0.24 . Transparent from 0.24 to 0.63 .

5. *p* - Nitrosodimethylaniline.

Fig. 5, plate 1.

P. 32 S.and J.

Dark green crystalline powder.

In solution; brownish yellow; clear yellow.

Saturated.

Angle 23'.4. Depth 0. to 0.21 mm.

Strong absorption in violet and blue increasing towards the ultra violet. A remarkably transparent region extends from 0.30 to 0.375 . All the strong lines between 0.324 and 0,363 are transmitted with almost no decrease in intensity.* A very round band stretched from 0.375 to 0.488 with its maximum at 0.432 . Complete transparency from 0.49 to 0.63 .

6. Resorcine (techn. pure.) (M.)

Fig. 4, plate 1.

P. 45 S. and J.

White crystalline lumps.

In solution; colorless.

Nearly Saturated.

Angle 29'.3 .Depth 0 to 0.27 mm.

No visible absorption. Very faint yellow in a layer a decimeter thick. The absorption ends very abruptly and shows an almost vertical right line determined by 0.287 and 0.293 .

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* R. W. Wood. "On Screens Transparent only to Ultra-Violet Light and their Use in Spectrum Photography".Phil. Mag. v. 5, Feb. 1903 pp. 257-263.

7. Naphthol Yellow. (A.) Naphthol Yellow S. (M.) Sodium salt of dinitro-α-naphthol-β-monosulphonic acid.

Fig. 6, plate 2.

No. 4 S. and J.

Orange yellow powder.

In solution; brownish yellow; pure yellow.

Saturated, (heated).

Angle 31'.2. Depth 0 to 0.29 mm.

Intense band in violet, ultra-violet side invisible. Absorption decreases from 0.20 towards 0.335 . Transparent region around 0.335 . A pair of overlapping bands extend from about 0.345 to 0.465 . Their maximum absorption is at 0.385 and their least absorption is at 0.41 . Very transparent from 0.465 to beyond 0.63 .

8. Aurantia. Ammonium salt of hexanitro-diphenylamine.

Fig. 7, plate 2.

No. 6 S. and J.

Reddish brown crystals.

In solution; dull red yellow.

10.00 g. per liter, (filtered).

Angle 42'.5. Depth 0 to 0.36 mm.

General absorption in violet. Absorption decreases from 0.20 towards 0.28 . Transparent region from 0.28 to 0.33 Wide band from 0.33 to 0.49 with its maximum at 0.41 .

As the concentration increases the absorption encroaches much faster on the transparent region in the ultra-violet than on the limit in the yellow. Very transparent to yellow and orange.

9. Fast Yellow. (B.) Sodium salt of amidoazotoluone-di-sulphonic acid.

Fig. 8, plate 2.

No. 9 S. and J.

Brownish yellow powder.

In solution; brownish yellow; yellow.

15.00 g. per liter.

Angle 23'.4 .Depth 0 to 0.21 mm.

Absorption in violet and blue. Absorption decreases gradually from 0.20 to semi-transparency at about 0.34 . A wide, diffuse band extends from this region to about 0.475 Its maximum is at 0.40 . Transparent from 0.475 to 0.63 .

10. Orange G. (A.) Sodium salt of benzene-azo-β-naphthol-disulphonic acid G.

Fig. 9, plate 2.

No. 14 S. and J.

Yellowish red powder.

In solution; red; yellow.

Saturated, (heated).

Angle 21'.3. Depth 0 to 0.18 mm.

Strong absorption in blue and green. Sharp on yellow edge. Two untra-violet bands meet at about 0.29 in a semi-transparent spot. The maximum of the less refrangible band is 0.325 . This strong band meets a very weak one at 0.365 . The centre of the weak band is 0.39 . The weak band joins an intense one at 0.42 . This last band joins a still stronger band, from which it is not resolved, at 0.485 . The maximum of the stronger band is at 0.505 . Absorption ceases at 0.53 . Complete transparency to 0.63 .

11. Ponceau 2 G. (M.) Sodium salt of benzene-azo-β-naphthol-di-sulphonic acid R.

Fig. 10, plate 3.

NO. 15 S. and J.

Bright red powder.

In solution; yellowish red; yellow.

7.00 g. per liter, (filtered).

Angle 27'.3. Depth 0 to 0.25 mm.

Comparatively weak band in the blue-green with a shadowy, fainter companion on the yellow side. Absorption decreases gradually from 0.20 to 0.34 . The nearly transparent region from 0.34 to 0.44 is interrupted by a very faint band having its maximum at 0.39 . The pair of stronger bands extend from 0.44 to 0.545 . Transparent from 0.545 to

0.63 . Same empirical formula as No. 10. No. 10 is derived from the G acid while No. 11 is a salt of the R acid.

12. Chrysoïdine. Hydrochloride of diamidoazo-benzene.

Fig. 11, plate 3.
No. 17 S. and J.
Reddish brown powder.
In solution; brown; yellow.
10.00 g. per liter, (filtered).
Angle 23'.4. Depth 0 to 0.21 mm.

Absorption in violet, blue and green with maximum in the indigo. Absorption decreases from 0.20μ to 0.33μ . Transparent from 0.33μ to 0.36μ . A pair of broad, unseparated bands absorb from 0.36μ to 0.54μ . The band of greater refrangibility is the more intense and has its maximum at 0.43 . Transparent from 0.54μ to 0.63μ . The less refrangible band disappears first on dilution . A five-strip negative shows that the outer boundaries of the pair of bands are steep and definite.

13. Chromotrope 6 B (M.). Sodium salt of p-acetamidobenzene-azo-1:8 - dioxy-naphthalene-3:6 disulphonic acid.

Fig. 12, plate 3.

No. 38 S. and J.

Grayish brown powder.

In solution; red; pink.

5.71 g. per liter.

Angle 11'.7. Depth 0 to 0.11 mm.

Strong absorption in green-yellow. Transparent from 0.35μ to 0.465 . A strong band has its beginning at 0.465 and its maximum at 0.515μ . The less refrangible side joins a weak companion band extending into the orange and red. More dilute solutions show that the intense band is symmetrical with respect to its maximum until it joins the associated band. More concentrated solutions show very distinctly the weaker band in the orange-red.

14. Azo Coccine 2 R. (A.) Sodium salt of xylene-azo-α-naphthol-p-sulphonic acid.

Fig. 13, plate 3.

No. 50 S. and J.

Reddish brown powder.

In solution; salmon pink; salmon pink.

Saturated, (heated).

Angle 27'.3. Depth 0 to 0.25 mm.

Narrow band in the blue-green. An absorption band of very indefinite edges extends from about 0.48 to 0.53 with its maximum at 0.505 μ. Transparent from 0.53 to 0.63 .

15. Brilliant Orange G. (M.) Sodium salt of xylene-azo-α-naphthol-disulphonic acid.

Fig. 14, plate 4.

No. 54 S. and J.

Cinnibar red powder.

In solution; yellowish red; deep yellow.

7.00 g. per liter

Angle 23'.4. Depth 0 to 0.21 mm.

Intense absorption in blue-green and blue. Very sharp on the yellow side. Absorption decreases from 0.20 to weak absorption at 0.295 , then increases to maximum absorption at 0.32 . At 0.355 semi-transparency obtains. A definite band has its maximum at 0.395 μ and joins the next band at 0.43 . The next band has its maximum at 0.48 and joins

the adjacent band at 0.505 . The final band has a maximum at 0.52 . Absorption ends at 0.545 . Complete transparency to 0.63/ . The band at 0.395 disappears rapidly with dilution. Same empirical formula as solution No. 14.

16. Ponceau 2 R. (A.), (M.) Sodium salt of xylene-azo-β-naphthol-disulphonic acid.

Similar to fig. 15, plate 4.

No. 55 S. and J.

Brownish red powder.

In solution; red; pink.

5.00 g. per liter (heated).

Angle 27'.3. Depth 0 to 0.25 mm.

Hazy-edged band in the blue-green. Similar absorption to that of solution No. 17 in the ultra-violet and identical with it in the visible region.

17. Ponceau 3 R. (A.), (M.) Sodium salt of ψ-cumene-azo-β-naphthol-disulphonic acid.

Fig. 15, plate 4.

No. 56 S. and J.

Dark red powder.

In solution; red; pink.

5.00 g. per liter, (heated).

Angle 29'.3. Depth 0 to 0.27 mm.

An absorption band is in the bluo-green. It has its maximum at 0.50 and extends from about 0.47 to 0.54 . Transparent from 0.54 to 0.63 .

18. Crystal Ponceau 6 R. (A.), (M.) Sodium salt of α-naphthalene-azo-β-naphthol-disulphonic acid.
Similar to fig. 15, plate 4.
No. 64 S. and J.
Brownsih red crystals with golden reflex.
In solution; light red; pink.
5.00 g. per liter, (heated).
Angle 27'.3 . Depth 0 to 0.25 mm.

Hazy-edged band in the blue-green and green. Similar absorption to that of solution No. 17. The visible band extends from 0.465 to 0.56 with its maximum at 0.51 .

19. Bordeaux B. (M.) Sodium salt of α-naphthalene-azo-β-naphthol-disulphonic acid.
Fig. 16, plate 4.
No. 65 S. and J.
Brown powder.
In solution; red; red.
4.18 g. per liter.
Angle 42'.5. Depth 0 to 0.36 mm.

Hazy edged band in the green. Band from 0.485 μ to 0.545 μ with maximum at 0.515 μ. The least refrangible ends for all the spectrograms slope thus showing that there is some general absorption in the orange. More concentrated solutions show that the greatest transparency occurs at 0.414 μ.

Same empirical formula as No.18.

20. Coccinine B. (M.) Sodium salt of p-methoxy-toluene-azo-β-naphthol-disulphonic acid.

Similar to fig. 15, plate 4.

No. 73 S. and J.

Dark red powder.

In solution; bright red; red.

13.64 g. per liter.

Angle 12'.8. Depth 0 to 0.11 mm.

Strong absorption in green yellow. Similar to solution No. 17 save that a weak absorption band seems to have the limits 0.315 μ and 0.355 μ with a maximum at 0.33. Intense band from 0.465 μ to 0.555 with a maximum at 0.510 μ. Transparent from 0.555 μ to 0.63 μ. Very concentrated solution or deeper layers show that the transparent region on both sides of 0.41 μ becomes opaque much faster than the orange and red region. Red is transmitted when all shorter wave-lengths are absorbed completely. The solution exhibits strong dispersive power.

21. Eosamine B. (A.) Sodium salt of p-cresol-methyl-ether-azo-α-naphthol-disulphonic acid.

Fig. 17, plate 4.

No. 74 S. and J.

Reddish brown powder.

In solution; yellowish red; pink.

8.89 g. per liter.

Angle 21'.3. Depth 0 to 0.18 mm.

Strong band in blue-green and green. Intense, round band from 0.465μ to 0.565μ with its maximum at about 0.52 . Transparent from 0.565 to 0.63μ . Same empirical formula as NO. 20.

22. Erika B. (A.) Sodium salt of methyl-benzenyl-amido-thio-xylenol-azo-α-naphthol-disulphonic acid.

Fig. 18, plate 5.

No.78 S. and J.

Reddish brown powder.

In solution; red; pink.

6.67 g. per liter.

Angle 19'.5. Depth 0 to 0.18 mm.

Strong absorption in blue, green, and green yellow. Two unresolved bands absorb strongly from 0.46 to 0.59μ . The more refrangible band is of greater intensity than its

companion and has its maximum at 0.52 . Slight absorption in the orange is followed by greater transparency in the red.

23. Emin Red. (A.) Sodium salt of methyl-benzenyl-amido-thioxylenol-azo-β-naphthol-sulphonic acid.

Fig. 19, plate 5.

No. 80 S. and J.

Red powder.

In solution; red; pink.

Saturated, (heated).

Angle 31'.2. Depth 0 to 0.29 mm.

Weak hazy absorption in blue and green. Strong absorption from 0.20 to about 0.35 then a rather rapid decrease in absorption sets in. From 0.38 to 0.45 a semi-transparent region exists. A round band extends from 0.45 to 0.54 . Its maximum is near 0.495 . The less refrangible side of this band is far more definite than its ultra-violet edge. Transparent from 0.54 to 0.63 .

24. Janus Green (M.) Chloride of safranine-azo-dimethylaniline.

No. 81 S. and J.

Olive green crystalline powder.

In solution; blue; blue.

4.60 g. per liter.

Angle 17'.0. Depth 0 to 0.14 mm.

Band in orange and orange-red. Transparent to pure red. Very general absorption in ultra-violet decreasing gradually from 0.20 to 0.40 . Transparent from 0.40 to 0.515. . The absorption band begins at 0.515 .

25. Tropaeoline O. (C.) Sodium salt of p -sulphobenzene-azo-resorcinol.
Similar to fig. 42, plate 11.
No. 84 S. and J.

Brown powder.

In solution; wine color; yellow.

Saturated, (heated).

Angle 25'.5. Depth 0 to 0.21 mm.

Faint absorption in the violet. Similar absorption to that of solution No. 81. Weak absorption from 0.20 to 0.275 . Transparent from 0.275 to 0.325 . A weak, hazy-band extends from 0.325 to 0.41 with it maximum around 0.37 . Transparent from 0.41 to 0.63 .

26. Tropaeoline 000 No. 1. Sodium salt of p-sulpholbenzene-azo-α-naphthol.

Similar to fig. 14, plate 4.

No. 85 S. and J.

Reddish brown powder.

In solution: red; salmon pink.

6.67 g. per liter.

Angle 21'.3. Depth 0 to 0.18 mm.

Absorption in violet, blue and green. Similar absorption to that of solution No. 15. Rather strong absorption continues from 0.20 to about 0.33 and then decreases rapidly to semi-transparency. A tolerably transparent region is from 0.35μ to 0.37μ. Three unresolved bands with maxima at about 0.41μ, 0.48μ and 0.52μ follow. The intermediate points of less intensity of absorption are 0.435μ and 0.450. At 0.545μ the absorption ceases. Transparent from 0.545μ to 0.63μ.

27. Tropaeoline 000 No. 2. Sodium salt of p-sulphobenzene-azo-β-naphtol.

No. 86 S. and J.

Bright orange powder.

In solution; deep red; salmon pink.

14.00 g. per liter.

Angle 21'.3. Depth 0 to 0.18 mm.

Visible absorption and spectrogram identical with No. 26. Similar absorption to that of solution No. 15. Nos. 26 and 27 have the same empirical formulae but differ by α and β in the naphtol.

28. Methyl Orange III. (P.) Sodium salt of p-sulphobenzene-azo-dimethylaniline.

Fig. 20, plate 5.

No. 87 S. and J.

Ochre yellow powder.

In solution; red; yellow.

Saturated, (heated).

Angle 27'.3. Depth 0 to 0.25 mm.

Absorption in blue and green. A strong band extends from 0.36 to 0.525 . This band is very round with its maximum at 0.44 . Transparent from 0.525 to 0.63 .

29. Tropaeoline 00, (C.) Sodium salt of p-sulphobenzene-azo-diphenylamine.

Similar to fig. 22, plate 6.

No. 88 S. and J.

Yellow powder.

In solution; yellowish red; yellow.

6.00 g. per liter, (heated and filtered).

Angle 25'.5. Depth 0 to 0.21 mm.

Delicate absorption in violet and blue. Similar absorption to that of solution No. 32. The extreme ultra-violet absorption is weak because the lines near 0.23 show on all three photographic strips. From 0.385 to 0.47 a weak absorption band obtains with its maximum at 0.43 . The substance is very transparent to yellow and red. Nos. 29 and 32 have the same empirical formulae. No. 29 is the para compound and No. 32 is the meta. No. 29 shows weaker absorption than No. 32.

30. Curcumeine (A.) Mixture of nitrated diphenylamine yellow with nitrodiphenylamine.

Fig. 21, plate 5.

No. 91 S. and J.

Ochre yellow powder.

In solution; red; yellow.

Saturated, (heated).

Angle 27'.3. Depth 0 to 0.25 mm.

Absorption in violet, blue and blue-green. Absorption complete at 0.20 and decreases very gradually with a comparatively definite contour to 0.455 . Transparent from 0.455 to 0.63 .

31. Azo Acid Yellow. (A.) Azo Yellow, conc'. (M.) Mixture of nitrated diphenylamine yellow with nitro-diphenylamine.

Similar to fig. 21, plate 5.

No. 92 S. and J.

Ochre yellow powder.

In solution; brownish yellow, yellow.

Saturated, (heated).

Angle 27'.3. Depth 0 to 0.25 mm.

Strong absorption in violet, blue and blue-green. Similar absorption to that of solution No. 30. Absorption is nearly complete and uniform from 0.20 to about 0.39 . Then the

absorption decreases in a gently sloping curve to about 0.505μ. Transpatent to yellow and red. Nos. 30 and 31 are mixtures of the same constituents and have very similar regions of absorption.

32. Metanil Yellow. (A.). Sodium salt of m-sulphobenzene-azo-diphenylamine.

Fig. 22, plate 6.

No. 95 S. and J.

Brownish yellow powder.

In solution; yellowish red; yellow.

4.29 g. per liter, (filtered).

Angle 23'.4. Depth 0 to 0.21 mm.

Absorption in violet and blue. A band with very indefinite periphery extends from about 0.36μ to 0.47μ. The maximum is near 0.41μ. Transparent to yellow and red. A very concentrated solution shows complete absorption from 0.20μ to 0.51μ with a semi-transparent spot at 0.34μ and maximum absorption at 0.40μ. Absorption ceases abruptly at 0.535μ.

33. Naphthylamine Brown. Sodium salt of p-sulphonaphthalene-azo-α-naphthol.

Fig. 23, plate 6.

No. 101 S. and J.

Brown powder.

In solution; reddish brown; almost colorless.

11.11 g. per liter, (heated and filtered).

Angle 30'.0. Depth 0 to 0.45 mm.

Very weak, general, indefinite absorption for all colors of shorter wavelengths than the yellow. A maximum of transparency is about 0.43 . The apparent absorption at 0.52 is much exaggerated by the lack of relative sensitiveness of the photographic film at this spot. Very slight absorption from 0.55 to 0.63 . A weaker solution presented only ultra-violet absorption.

34. Fast Red. A. (A.) New Coccine O (M.) Sodium salt of

p-sulphonaphthalene-azo-β-naphthol.

Fig. 24, plate 6.

No. 102 S. and J.

Brownish red powder.

In solution; red; pink.

5.00 g. per liter, (heated).

Angle 27'.3. Depth 0 to 0.25 mm.

Hazy absorption in blue-green and general absorption in blue. Muddy looking solution. Two partially resolved bands extend from 0.415 to 0.54 with maxima of absorption at about 0.45 and 0.505 . The less refrangible band is the more intense. Orange and red are transmitted but the sloping end of the photograph shows that slight, general absorption is present in the orange. Nos. 33 and 34 have the same empirical formulae. They differ by α and β naphtol.

35. Azo Rubine S. (A.) Sodium salt of p-sulphonaphthalene-azo-α-naphthol-p-sulphonic acid.
Similar to figure 15, plate 4.
No.103 S. and J.

Brown powder.

In solution; red; pink.

10.00 g. per liter.

Angle 19'.5. Depth 0 to 0.18 mm.

Absorption in green. Much like solution No. 17 with slight difference in ultra-violet. Absorption decreases from 0.20 to 0.27. The strong lines at 0.255 and 0.275 are transmitted by the deepest layer. Absorption increases from 0.27 to a maximum at 0.315. Then the absorption decreases to approximate transparency at 0.36. Transparent from 0.36 to 0.465. Strong band from 0.465 to 0.555 with maximum at 0.51. The visible band is in the same place as the like band of No. 20 but the ultra-violet is different. Transparent to orange and red.

36. Fast Red, extra. (A.) Sodium salt of p-sulphonaphthalene-azo-β-naphthol-mono-sulphonic acid.

Similar to figure 15, plate 4.

No. 105 S. and J.

Reddish brown powder.

In solution; red; pink.

7.00 g. per liter.

Angle 27'.3. Depth 0 to 0.25 mm.

Absorption in blue-green and green. Absorption the same throughout as for No. 35 except the position of the visible band. No. 36 absorbs from 0.460 to 0.545 with the maximum at 0.505 . Same empirical formula as for No. 35.

37. New Coccine (A.) Sodium salt of p-sulphonaphthalene-azo-β-naphthol-disulphonic acid.

Similar to fig. 17, plate 4.

No. 106 S. and J.

Scarlet red powder.

In solution; yellowish red, pink.

10.00 g. per liter.

Angle 23'.4. Depth 0 to 0.21 mm.

Absorption in blue-green and green. Similar absorption to that of solution No. 21. Absorption decreases from 0.20 to transparency about 0.37 . A strong round band from 0.445 to 0.56 has its maximum at 0.51 . Transparent from 0.56 to 0.63 .

38. Fast Brown 3 B. (A.) Sodium salt of sulphonaphthalene-azo-α-naphthol.

Fig. 25, plate 7.

No. 111 S. and J.

Dark brown glistening powder.

In solution; reddish brown; faint brown.

15.00 g. per liter.

Angle 27'.3. Depth 0 to 0.25 mm.

All Aboard!

Don't miss it¡

Absorption most intense in blue-green and green with slight general absorption on both sides. A fairly strong band from 0.46 to 0.54 has its maximum at 0.51 . No definite band from 0.54 to 0.63 but general absorption is made evident by the slope of the end of the negative.

39. Mordant Yellow O. (M.) Sodium salt of sulphonaphthalene-azo-salicylic acid.

Similar to fig. 74, plate 19.

No. 116 S. and J.

Yellow powder.

In solution; reddish yellow; yellow.

10.00 g. per liter.

Angle 31'.2. Depth 0 to 0.29 mm.

Absorption in the violet only. Similar absorption to that of solution No. 129. Strong absorption from 0.20 to 0.28 . Slight weakening of absorption from 0.28 to 0.34 . Absorption attains a maximum at 0.36 and then slopes gradially, with a comparatively definite edge, to transparency at 0.44 . From this point to 0.63 complete transparency exists.

40. Dianil Yellow R. (M.)

Similar to fig. 42, plate 11.

No. 124 S. and J.

Orange yellow powder.

In solution; clear yellow; yellow.

Saturated.

Angle 31'.2. Depth 0 to 0.29 mm.

Faint absorption in violet. Similar absorption to that of solution No. 81. Absorption is comparatively strong at 0.20 and decreases to partial transparency near 0.295 . A tolerably weak band extends from this region to about 0.435 . Its maximum is indeterminate. Transparent from 0.44 to 0.63 .

41. Resorcine Brown. (A.) Sodium salt of xylene-azo-resorcin-azo-benzene-*p*-sulphonic acid.

Fig. 26, plate 7.

No. 137 S. and J.

Brown powder.

In solution; brown; yellow.

7.78 g. per liter.

Angle 23'.4. Depth 0 to 0.21 mm.

Strong absorption in the violet and blue. A more concentrated solution exhibited absorption in the green and yellow. A long band or region of absorption extends from 0.35 to 0.52 . The maximum is near 0.395 . There is a slight minimum of absorption at 0.48 . The presence of a weaker, less refrangible band increasing in intensity at 0.48 is more marked as the concentration is increased.

More concentrated solutions show that the transparency in the ultra-violet rapidly disappears whereas the bands do not encroach as rapidly on the yellow. Transparent from 0.53 to 0.63 . The absorption of the concentrated solutions is like that of solution No. 77 figure 40.

42. Acid Brown. (D.) Sodium salt of bi-sulphobenzene-disazo-α-naphtol.

Similar to fig. 7, plate 2.

No. 138 S. and J.

Brown powder.

In solution; brown; yellow.

7.50 g. per liter.

Angle 25'.5. Depth 0 to 0.21 mm.

Absorption in violet and blue. Similar absorption to that of solution No. 8. Very weak absorption from 0.20 to 0.29 . Transparent to continuous background of spark from 0.29 to 0.33 . Weak, indefinite absorption band from 0.33 to 0.48 with maximum indeterminate. Transparent to yellow, orange and red.

43. Ponceau B O., extra. (A.) Sodium salt of benzene-azo-benzene-azo-β-naphthol-disulphonic acid.

Similar to figure 17, plate 4.

No. 146 S. and J.

Light brown powder.

In solution; yellowish red; pink.

7.00 g. per liter.

Angle 21'.5. Depth 0 to 0.20 mm.

Strong absorption in blue and green. Similar absorption to that of solution No. 21. Absorption decreases from 0.20 to 0.295 , and then increases to a maximum near 0.345 . This band fades to semi-transparency about 0.4 . Transparency continues to 0.44 where a strong, round band begins. The last band ends at 0.565 . Its maximum is at 0.51 . Transparent from 0.565 to 0.63 . Absorption from this band moves more rapidly towards the ultra-violet than towards the red with increasing concentration. Same empirical formula as No. 42.

44. Janus Red B. (M.) Chloride of trimethyl-amido-benzene-azo-m-toluene-azo-β-naphthol.

Similar to figure 25, plate 7.

No. 149 S. and J.

Reddish brown powder.

In solution; yellowish red; faint yellowish red.

Saturated.

Angle 54'.6. Depth 0 to 0.50 mm.

Pointed, V-shaped, weak band in the blue-green. Similar absorption to that of solution No. 38. Absorption is strong at 0.20 and decreases gradually and in a poorly defined manner

to transparency at 0.375 . The transparent region continues to 0.455 . The absorption band lies between 0.455 and 0.540 with its maximum at 0.51 . Slight, general absorption in the yellow and orange but transparent to the red.

45. Cloth Red G. (O.) Sodium salt of toluene-azo-toluene-azo-β-naphthol-monosulphonic acid.

Fig. 27, plate 7.

No. 153 S. and J.

Reddish brown powder.

In solution; red; faint pink.

8.33 g. per liter, (heated and filtered).

Angle 31'.2. Depth 0 to 0.29 mm.

Bands in blue-green and green, with hazy edges and weak general absorption in both directions. A band extends from 0.445 to 0.55 and appears to be composed of a stronger band with a weaker, more refrangible, unresolved companion. Their maximum of absorption is at 0.515 . The slant at the end of the negative shows that weak, general absorption is exerted in the orange. Transparent to the red.

46. Cloth Red O. (M.) Sodium salt of toluene-azo-toluene-azo-β-naphthol-disulphonic acid.

Fig. 28, plate 7.

No. 154 S. and J.

Dark brown powder.

In solution; deep red; very faint red.

6.36 g. per liter, (warmed and filtered).

Angle 33'.2. Depth 0 to 0.30 mm.

Maximum of absorption in blue-green with weak absorption in yellow and orange. Absorption band starts at 0.485 μ, attains its maximum at 0.52 μ, and is dissipated in weak, general absorption about 0.555 μ. The end of the negative slants appreciably. Transparent to red.

47. Cloth Red 3 G A. (A.) Sodium salt of toluene-azo-toluene-azo-β-naphthyl-amine-monosulphonic acid.

Fig. 29, plate 8.

No. 155 S. and J.

Brownish red powder.

In solution; reddish brown; light brown.

Saturated, (heated).

Angle 1° 57'. Depth 0 to 1.07 mm.

General absorption in violet, also a maximum of absorption in the blue-green and green. Absorption is about complete at 0.20 μ and increases very gradually, with hazy contour, to semi-transparency at about 0.42 μ. Semi-transparency from 0.42 μ to 0.49 μ. Weak band from 0.49 μ to 0.54 μ. Transparent from 0.54 to 0.63 μ.

48. Ponceau 4 R B. (A.) Sodium salt of sulphobenzene-azo-benzene-azo-β-naphthol-mono-sulphonic acid.

Fig. 30, plate 8.

No. 160 S. and J.

Reddish brown powder.

In solution; yellowish red; pink.

10.00 g. per liter, (heated).

Angle 19'.5. Depth 0 to 0.18 mm.

Strong absorption in blue-green and green. At 0.455 μ the strong band begins and extends to 0.565 μ with its maximum about 0.51 μ. Transparent from 0.565 μ to 0.63 μ.

49. Biebrich Scarlet. (K.) Sodium salt of sulphobenzene-azo-sulphobenzene-azo-β-naphthol.

Similar to fig. 30, plate 8.

No. 163 S. and J.

Reddish brown powder.

In solution; red; pink.

6.00 g. per liter.

Angle 19'.5. Depth 0 to 0.18 mm.

Absorption band in blue-green and green. Absorption decreases from 0.20 μ to about 0.32 μ where a semi-transparent region appears. This is followed by an absorption band with its maximum at 0.355 μ. Slight absorption from 0.39 μ to 0.45 μ. A definite band starts at 0.45 μ, reaches a maximum near 0.51 μ and ends at 0.555 μ. Transparent from 0.555 μ to 0.63 μ. A solution of 10.00 g. per liter showed almost

complete absorption from 0.20 to 0.36 . From 0.395 to 0.445 only the first photographic strip received light. The band is very round from 0.445 to its end at 0.585 . Transparent to orange and red . Same empirical formula as No. 48 and almost identical visible absorption.

50. Wool Black (A.) Sodium salt of sulphobenzene-azo-sulphobenzene-azo-p-tolyl-β-naphthylamine.

Fig. 31, plate 8.

No. 166 S. and J.

Bluish black powder.

In solution; purple; light purple.

5.56 g. per liter, (filtered).

Angle 35.'1. Depth 0 to 0.32 mm.

Hazy band in yellow spreading indefinitely into the orange. Transmits bright red. At 0.49 a region of absorption commences which seems to consist of a hazy central band with a weak, washed-out, companion on each side. The chief maximum is about 0.54 . Absorption is very weak from 0.60 to 0.63 . A very concentrated solution shows that the maximum of transparency is near 0.44 .

51. Ponceau 6 R B. (A.) Sodium salt of sulphotoluene- azo-toluene-azo-β-naphtol-α-sulphonic acid.

Fig. 32, plate 8.

No. 169 S. and J.

Reddish brown powder.

In solution; scarlet red; pink.

5.38 g. per liter.

Angle 31'.2. Depth 0 to 0.29 mm.

Strong band in the green which is more definite on the blue side than on the yellow border. Strong band from 0.465 μ to 0.565 μ. The maximum is at 0.51 μ. The band is probably composed of two unresolved bands of which the weaker lies nearer the red. Transparent from 0.565 μ to 0.63 μ.

52. Blue Black. (B.) Sodium salt of sulpho-β-naphthalene-azo-α-naphthalene-azo-β-naphthol-disulphonic acid.

No. 186 S. and J.

Bluish black powder.

In solution; bluish violet; violet.

0.69 g. per liter, (filtered).

Angle 33'.2. Depth 0 to 0.30 mm.

Very indefinite absorption in green-yellow, yellow and orange, with maximum in yellow. Absorption is strong at 0.20 μ and decreases gradually to about 0.34 μ. Approximately transparent from 0.4 μ to 0.5 μ. Absorption starts near 0.50 μ, increases to a maximum about 0.54 μ, and decreases to weak, general absorption from 0.58 μ to 0.63 μ.

53. Anthracene Yellow C. (C.) Sodium salt of thio-di-benzene-disazo-di-salicylic acid.

Similar to fig. 42, plate 11.

No. 190 S. and J.

Brownish yellow powder.

In solution; muddy yellow brown; greenish yellow.

6.00 g. per liter, (filtered).

Angle 21'.3 . Depth 0 to 0.18 mm.

Absorption in violet. Somewhat similar absorption to that of solution No. 81. Absorption decreases from 0.20 μ to a semi-transparent strip at about 0.295 μ. Beyond this strip a band with hazy contour extends as far as 0.41 μ with its maximum at about 0.34 μ. Transparent from 0.41 μ to 0.63 μ.

54. Bismarck Brown. (A.) Hydrochloride of benzene-disazo-phenylene-diamine.

Fig. 11, plate 3.

No. 197 S. and J.

Dark brown powder.

In solution; brown, yellow.

30.00 g. per liter, (filtered).

Angle 19'.5. Depth 0 to 0.18 mm.

Visible and photographic absorption identical with that of solution No. 12.

55. Vesuvine (B.) Hydrochloride of toluene-disazo-m-tolylene-diamine.

Fig. 11, plate 3.

No. 201 S. and J.

Dark brown powder.

In solution; reddish brown; yellow.

4.29 g. per liter.

Angle 31'.2. Depth 0 to 0.29 mm.

Visible and photographic absorption identical with that of solution No. 12.

56. Congo Orange G. (A.) Sodium salt of diphenyl-disazo-phenetol-β-naphthylamine-disulphonic acid.

Fig. 33, plate 9.

No. 217 S. and J.

Brownish red powder.

In solution; reddish yellow; yellow.

5.38 g. per liter.

Angle 23'.4. Depth 0 to 0.21 mm.

Hazy absorption in blue, blue-green and green with maximum in the green. Tolerably strohg absorption decreases from 0. 20μ to a weak minimum near 0.32μ and then increases to a maximum about 0.36μ. A semi-transparent region lies between 0.405μ and 0.44μ. A weak, hazy band begins at 0.44μ and continues to 0.475μ, at which point it joins a more intense band. The latter has its maximum at 0.505μ and then de-

creases to transparency at 0. 53μ . Transparent from 0. 53μ to 0.63μ . More concentrated solutions emphasize all the maxima of absorption just outlined and the minimum at 0.42μ .

57. Chrysamine G. (A.) Sodium salt of diphenyl-disazo-bi-salicylic acid.

Similar to fig. 34, plate 9.

No. 220 S. and J.

Yellowish brown powder.

In solution; brownish yellow; faint yellow.

7.00 g. per liter, (heated and filtered).

Angle 35'.1. Depth 0.26 to 0.58 mm.

No visible absorption unless, perhaps, a faint weakening of the extreme violet. Similar absorption to that of solution No. 58 . For the layer used the absorption is nearly complete from 0.20μ to 0.29μ . The continuous background is transmitted from 0.29μ to 0.30μ . The limit of the ultra-violet absorption is approximately a straight line joining the wave-lengths 0.365μ and 0.395μ at the opposite edges of the negative. Transparent from 0.395μ to 0.63μ . More dilute solutions and wedges of liquid tapering to infinitesimal thickness show that the ultra-violet absorption is very weak.

58. Cresotine Yellow G. (M.) Sodium salt of diphenyl-disazo-bi-o-cresol-carboxylic acid.

Fig. 34, plate 9.

No. 221 S. and J.

Yellowish brown powder.

In solution; yellow; faint yellow.

Saturated.

Angle 39'.0. Depth 0 to 0.36 mm.

Absorption in violet and indigo. The solution has a peculiar odor. A washed-out band begins at 0.31μ, passes through a maximum near 0.355μ, and then fades away at 0.44μ. Transparent from 0.44 to 0.63μ.

59. Congo Red. (A.) Sodium salt of diphenyl-disazo-bi-naphthionic acid.

Fig. 35, plate 9.

No. 240 S. and J.

Reddish brown powder.

In solution; red; yellowish red.

5.90 g. per liter.

Angle 27'.3. Depth 0 to 0.25 mm.

Absorption in blue, blue-green and green with maximum nearer the green end. Transparency is terminated at 0.42μ by a pair of wide hazy-bands of which the more refrangible is the weaker. The chief maximum is at 0.505μ. Absorption ends at 0.545 .

Transparent from 0.545 to 0.63 . More concentrated solutions show that the ultra-violet and visible bands soon run together, whereas the absorption does not advance much towards the orange.

60. Congo Corinth G. (A.) Sodium salt of diphenyl-disazo-naphthionic-α-naphthol-sulphonic acid.

Similar to fig. 25, plate 7.

No. 242 S. and J.

Greenish black powder.

In solution; brownish red, red.

5.38 g. per liter, (heated).

Angle 27'.3. Depth 0 to 0.25 mm.

Absorption in blue-green, green and yellow. Very general absorption at the red border. Similar absorption to that of solution No. 38. Absorption band from 0.46μ to 0.555 with its maximum near 0.515μ . The end of the negative slants considerably showing that general absorption continues into the orange. Transparent to red. Same empirical formula as No. 61 but different constitution.

61. Congo Rubine (A.) Sodium salt of diphenyl-disazo-naphthionic acid-β-naphthol-sulphonic acid.

Fig. 36, plate 9.

No. 243 S. and J.

Greenish crystalline powder.

In solution; bluish red; dull red.

Saturated, (warmed).

Angle 39'.0. Depth 0.26 to 0.62 mm.

Absorption in blue green. A layer about 2 mms. deep absorbs all the visible spectrum except the orange and red. Absorption band from 0.485μ to 0.55μ with its maximum at 0.52μ. Transparent from 0.55μ to 0.63μ. Same empirical formula as No. 60 but different constitution.

62. Anthracene Red. (I.) Sodium salt of nitrodiphenyl-disazo-salicylic-α-naphthol-sulphonic acid.

Similar to fig. 32, plate 8.

No. 262 S. and J.

Brownish red powder.

In solution; deep red; pink.

7.50 g. per liter.

Angle 27'.3. Depth 0 to 0.25 mm.

Hazy-edged band in the blue-green and green. Similar absorption to that of solution No. 51. Absorption decreases from 0.20μ to semi-transparency at 0.29μ. About 0.31μ a well-rounded, hazy-edged band starts passes through its maximum near 0.36μ, and ceases at 0.42μ. Partial transparency from 0.42μ to 0.465μ. An absorption band prevents transmission from 0.465μ to 0.55μ. Its maximum is near 0.51μ. Transparent from 0.55μ to 0.63μ. Less concentrated solutions

show that the ultra-violet absorption is comparatively weak.

63. Congo Orange R. (A.) Sodium salt of ditolyl-disazo-phenetol-β-naphthylamine disulphonic acid.

Similar to fig. 29, plate 8.

No. 275 S. and J.

Yellowish red powder.

In solution; brown, yellowish brown.

5.00 g. per liter, (warmed and filtered).

Angle 39'.0. Depth 0 to 0.36 mm.

Indefinite, general absorption in the blue and blue-green. The liquid is not clear but behaves somewhat like and emulsion. Similar absorption to that of solution No. 47. Absorption decreases from 0.20μ to about 0.29μ and then remains about constant as far as 0.365μ. From this point it decreases to very weak, general absorption at 0.43μ. A slight increase in absorption has its maximum at 0.515μ. It is partly, but not entirely, due to the weak spot of the Seed emulsion. Transparent from 0.54μ to 0.63μ. Deeper layers of greater concentration show the minimum of absorption to be the region around 0.455μ.

64. Benzopurpurine 6 B. (A.) Sodium salt of ditolyl-disazo-bi-α-naphthylamine-sulphonic acid.

Similar to fig. 37, plate 10.

No. 278 S. andJ.

Red powder.

In solution; red; brownish red.

7.78 g. per liter, (filtered).

Angle 29'.3. Depth 0 to 0.27 mm.

Hazy-edged band in blue and green. Similar absorption to that of solution No. 67. Strong absorption from 0.415µ to 0.55µ. The chief maximum of absorption is at 0.51µ. Probably two hazy, unresolved bands with more-refrangible weaker component. Transparent from 0.55µ to 0.63µ. Weaker solutions show more rapid increase of transparency on the ultra-violet side of the visible band than on the red side.

65. Benzopurpurine B. (A.) Sodium salt of ditolyl-disazo-bi-β-naphthylamine-β-sulphonic acid.

Similar to fig. 37, plate 10.

No. 279 S. and J.

Brown powder.

In solution; reddish brown; brown.

8.75 g. per liter.

Angle 25'.4. Depth 0 to 0.23 mm.

Same visible and photographic absorption as No. 64. Similar absorption to that of solution No. 67. Nos. 64 and 65 have the same empirical formulae but different chemical constitution.

66. Diamine Red B. (A.) Deltapurpurine 5 B. (M.) Sodium salt of ditolyl-disazo-bi-β-naphthylamine-sulphonic acid.

Similar to fig. 37, plate 10.

No. 280 S. and J.

Reddish brown powder.

In solution; yellowish red; pink.

6.36 g. per liter, (warmed and filtered).

Angle 25'.4. Depth 0 to 0.23 mm.

Same visible and photographic absorption as No. 64. Similar absorption to that of solution No. 67. Nos. 64 and 66 have the same empirical formulae but different chemical constitutions.

67. Brilliant Congo R. (A.) Sodium salt of ditolyl-disazo-β-naphthylamine-monosulphonic-β-naphthylamine-disulphonic acid.

Fig. 37, plate 10.

No. 281 S. and J.

Brown powder.

In solution; yellowish red; yellowish red.

8.00 g. per liter.

Angle 31'.2. Depth 0 to 0.29 mm.

Hazy-edged band in blue and green. A pair of unresolved bands extend from 0.42μ to 0.56μ with their chief maximum at 0.515μ. The less refrangible band is the more intense. Transparent from 0.555μ to 0.63μ.

68. Diamine Red 3 B. (A.) Sodium salt of ditolyl-disazo-
bi-β-naphthylamine- -sulphonic acid.
Fig. 38, plate 10.
No. 282 S. and J.
Reddish brown powder.
In solution; reddish brown; brown.
7.00 g. per liter, (heated and filtered).
Angle 50'.7. Depth 0.64 to 1.10 mms.

Hazy-edged absorption in the blue-green and green. A pair of unresolved bands absorb from about 0.435μ to 0.545μ. Their maximum is near 0.515μ. The more refrangible band is weaker and more indefinite than its companion. Transparent from 0.545μ to 0.63μ.

69. Brilliant Purpurine R. (A.) Sodium salt of ditolyl-disazo-
naphthionic-β-naphthylamine-disulphonic acid.
Fig. 37, plate 10.
No. 283 S. and J.
Red powder.
In solution; red; pink.
8.75 g. per liter.

Angle 25'.4 . Depth 0 to 0.23 mm.

Same visible and photographic absorption as No. 67. Nos. 67 and 69 have the same empirical formulae but different chemical constitutions.

70. Rosazurine B. (B.) Sodium salt of ditolyl-disazo-bi-ethyl-β-naphthylamine-sulphonic acid.

Similar to fig. 37, plate 10.

No. 285 S. and J.

Brown powder.

In solution; red; pink.

7.00 g. per liter, (heated).

Angle 27'.3. Depth 0 to 0.25 mm.

Weak absorption in the green with very hazy blue boundary. Similar absorption to that of solution No. 67. The precise size and shape of the visible band matches very closely the corresponding band of solution No. 45 fig. 27. Absorption from 0.47μ to 0.55μ with the maximum near 0.515μ . Transparent from 0.55μ to 0.63μ .

71. Congo Corinth. Sodium salt of ditolyl-disazo-naphthionic-α-naphthol-p-sulphonic acid.

Similar to fig. 39, plate 10.

No. 286 S. and J.

Grayish black powder.

In solution; red; pink.

9.09 g. per liter, (very gritty; filtered often).

Angle 21'.5. Depth 0 to 0.20 mm.

General absorption in green, yellow and orange. Very weak and hazy towards the red. Similar absorption to that of solution No. 74. Weak, general absorption in ultra-violet permitting all strong lines to pass through the solution. It fades away about 0.35 μ. Several plates and films show that absorption begins again about 0.49 μ and becomes relatively small at 0.56 μ. Weak, general absorption, however, continues to 0.63 μ. The maximum of absorption is indeterminate. Saturated solutions gave the same general results.

72. **Azo Blue.** (By.) Sodium salt of ditolyl-disazo-bi-α-naphthol-p-sulphonic acid.

Somehwat like fig. 39, plate 10.

No. 287 S. and J.

Bluish black powder.

In solution; deep blue; reddish blue.

4.29 g. per liter.

Angle 23'.4. Depth 0 to 0.21 mm.

Hazy-edged absorption in green-yellow, yellow and orange. The red border is very indefinite and the maximum appears to be in the yellow. The absorption is like that of solution No. 74 except in so far as it is stronger than No. 74 in the orange. Comparatively weak absorption in the ultra-violet

from 0.20 to 0.355 . There are slight indications of two ultra-violet bands with the intervening region near 0.29 . Transparent from 0.36 to 0.49 . Absorption begins at 0.49 and increases to 0.53 , and then fades to partial transparency near 0.59 . Weak absorption from 0.59 to 0.63 .

73. Diamine Black B O. (C.) Sodium-salt of ethoxy-diphenyl-disazo-bi-amido-naphthol-sulphonic acid.

Suggested by fig. 39, plate 10.

No. 304 S. and J.

Black powder.

In solution; blue; blue.

7.50 g. per liter.

Angle 31'.2. Depth 0 to 0.29 mm.

Strong absorption in the yellow and orange with diffuse borders. Red is transmitted. The absorption is somewhat like that of solution No. 74 except in so far as it is stronger than No. 74 in the orange. Absorption decreases from 0.20 to about 0.37 . Transparent from 0.37 to 0.51 . Absorption extends from 0.51 into the clear red. The maximum of absorption is indefinite.

74. Benzopurpurine 10 B. (A.) Sodium salt of dimethoxy-diphenyl-disazo-binaphthionic acid.

Fig. 39, plate 10.

No. 307 S. and J.

Brownish red powder.

In solution; red; pink.

5.83 g. per liter.

Angle 23'.4. Depth 0.05 to 0.26 mm.

Chief absorption in the green. The visible band extends from about 0.48 to 0.55 with its maximum at 0.515 . The slanting end of the negative denotes general absorption in the orange.

75. Benzoazurine. Sodium salt of dimethoxy-diphenyldisazo-bi-a-naphthol-p-sulphonic acid.

Somewhat like fig. 39, plate 10.

No. 311 S. and J.

Bluish black powder.

In solution; reddish blue; blue.

7.50 g. per liter.

Angle 25'.5. Depth 0 to 0.21 mm.

No very definite visible band but a general weakening of the green, yellow, orange and red. The ultra-violet absorption is weak and ends near 0.355 . The region of general absorption begins about 0.51 and continues beyond 0.63 . There is a weak maximum near 0.53 . The end of the negative slants to an unusual degree. The contour of the weak band is V-shaped like the visible band for solution No. 74.

76. Diamine Green B. (C.) Sodium salt of diphenyl-disazo-phenol-disulpho-amidonaphthol-azo-nitrobenzene.

No. 372 S. and J.

Dull gray crystalline powder.

In solution; bluish green, bluish green.

3.00 g. per liter.

Angle 17'.0. Depth 0 to 0.14 mm.

Gradual absorption in the orange and red. Very weak absorption in the ultra-violet from 0.20μ to about 0.38 . No visible or photographic absorption between 0.38 and 0.6μ . General absorption begins about 0.6μ .

77. Congo Brown G. (A.) Sodium salt of sulpho-benzene-azo-resorcinol-azo-diphenyl-azo-salicylic acid.

Fig. 40, plate 10.

No. 379 S. and J.

Brown powder.

In solution; light brown; yellow.

4.67 g. per liter.

Angle 27'.3. Depth 0 to 0.25 mm.

Absorption in violet, blue and green. Very hazy at green side. Absorption decreases from 0.20 to a somewhat transparent region around 0.295μ . Maximum absorption at 0.365 . Absorption ceases at 0.53 . A weaker solution showed transparency from 0.29μ to 0.315 . Absorption from 0.315 to 0.428 . Maximum absorption at 0.365 , as before. Trans-

parent to yellow, orange, and red.

78. Congo Brown R. (A.) Sodium salt of sulpho-naphthlene-azo-resorcin-azo-diphenyl-azo-salicylic acid.

Fig. 40, plate 10.

No. 380 S. and J.

Dark brownish red powder.

In solution; reddish brown; yellow.

Saturated.

Angle 29'.3. Depth 0 to 0.27 mm.

Same visible and photographic absorption as No. 77. The change in the constitution is from benzene to naphthalene.

79. Fast Green O. (M.) Dinitroso-resorcinol. (Dioximidoquinone.)

Similar to fig. 29, plate 8.

No. 394 S. and J.

Grayish brown powder.

In solution; deep coffee brown; coffee brown.

Saturated, (heated).

Angle 1° 6'. Depth 0.05 to 0.66 mm.

General absorption in violet and blue. Similar absorption to that of solution No. 47. From 0.20 to 0.325 the absorption is complete. Absorption decreases with a long, gradual slope from 0.325 to a minimum of semi-transparency

at 0.475 μ. Then a weak band with maximum at 0.52 presents itself and continues to 0.54. Only very weak absorption is present from 0.54 to 0.63. With the same solution and the cell set for 35'.1 and 0.32 mm. the absorption was almost complete from 0.20 to 0.30 and then sloped gradually to transparency at 0.405. The band at 0.52 could not be discerned.

80. Naphthol Green B. (C.) Ferrous sodium salt of nitroso-β-naphthol-β-monosulphonic acid.
Fig. 41, plate 11.
No. 398 S. and J.
Dark green powder.
In solution; green, light green.
8.75 g. per liter, (boiled).
Angle 31'.2. Depth 0 to 0.29 mm.

Absorption in violet and in dark red. Absorption very strong from 0.20 μ to 0.31μ. Then the absorption decreases very gradually, with a long slant, to 0.455μ. From 0.455 to the orange the transparency is complete. Absorption begins again in the red.

81. Curcumine S. (A.) Sodium salt of the so-called azoxy-stilbene-disulphonic acid.
Fig. 42, plate 11.
No. 399 S. and J.

Brown powder.

In solution; yellow; faint yellow.

Saturated.

Angle 1°10'. Depth 0.11 to 0.75 mm.

Faint absorption in violet. Absorption decreases from 0.20 to 0.29μ. Transparent from 0.29μ to 0.34μ. Weak band from 0.34μ to 0.43μ, with maximum at 0.39μ. Transparent from 0.43μ to 0.63μ.

82. **Auramine O.** (B.) Hydrochloride of imido-tetramethyl-diamido-diphenyl-methane.

Fig. 43, plate 11.

No. 425 S. and J.

Sulphur yellow powder.

In solution; yellow; faint yellow.

Equal volumes of a saturated solution and of water, (filtered).

Angle 42'.5. Depth 0 to 0.36 mm.

Strong absorption in violet and indigo. Relatively transparent at 0.22μ. The continuous background of the spark indicates one band or, at most, two bands from 0.23μ to 0.275μ. Unusually transparent from 0.275μ to 0.345μ. A pair of partially resolved, intense bands absorb from 0.345 to 0.470μ. Their maxima lie at 0.365μ and 0.425μ. The

intervening partially transparent spot is near 0.385μ. The less refrangible band is the more intense and is very round. Transparent from 0.470μ to 0.63μ.

83. Malachite Green (M.) Oxalate of tetramethyl-di-p-amido-triphenyl-carbinol.

Similar to fig. 44, plate 11.

No. 427 S. and J.

Green metallic glistening plates.

In solution; greenish blue; greenish blue.

3.75 g. per liter.

Angle 25'.5. Depth 0 to 0.21 mm.

Strong double band in the orange and clear red. Deep red is transmitted. Similar absorption to that of solution No. 86 from 0.20μ to the yellow. All strong lines in the extreme ultra-violet are transmitted freely. An absorption band lies between 0.29μ and 0.33μ. A faint band has its maximum near 0.425μ. Strong absorption commences at 0.55μ.

84. Emerald Green. (B.) Sulphate or zinc-double-chloride of tetraethyl-diamido-triphenyl-carbinol.

Similar to fig. 44, plate 11.

No. 428 S. and J.

Golden glistening crystals.

In solution; green; green.

4.62 g. per liter.

Angle 31'.2. Depth 0 to 0.29 mm.

Compound band in the orange and red with the maximum in the red. The contour is hazy. Similar absorption to solution No. 86, from 0.20μ to the yellow, save that the band near 0.425μ is hardly discernible on the negative. Strong absorption begins at 0.57μ. For ultra-violet details see No. 84 above.

85. Light Green F.S. (B.) Sodium salt of dimethyldibenzyl-diamido-triphenyl-carbinol-trisulphonic acid.

Similar to fig. 44, plate 11.

No. 434 S. and J.

Brownish black powder.

In solution; green; green.

10.00 g. per liter.

Angle 21'.3. Depth 0 to 0.18 mm.

Strong band in the yellow, orange and red. Except for concentration, the absorption is the same as that of solution No. 86, hence for further details, refer to No. 86.

86. Acid Green, conc. (C.) Sodium salt of diethyldibenzyl-diamido-triphenyl-carbinol-trisulphonic acid.

Fig. 44, plate 11.

No. 435 S. and J.

Bright green dull powder.

In solution; deep green; green.

13.33 g. per liter.

Angle 25'.4. Depth 0 to 0.23 mm.

Strong band in orange and red with no return to transparency visible. Absorption in violet and blue. Absorption decreases from 0.20 to about 0.275 . Then a strong band begins having its maximum near 0.32 and returning abruptly to transparency at 0.34 . Transparent from 0.34 to 0.39 . A round band extends from 0.39 to 0.455 with its maximum at 0.425 . Transparent from 0.455 to 0.55 . Strong absorption commences at 0.55 and increases to complete opacity at 0.63 μ . Weaker solutions show conclusively the transparent region around 0.275 and also that the band at 0.425 vanishes most readily.

87. Fuchsine. (M.) Mixture of hydrochloride or acetate of pararosaniline and rosaniline.

Suggested by figs. 45 and 51, plates 12 and 13.

No. 448 S. and J.

Green crystalline powder.

In solution; deep red; red.

Angle 21'.3. Depth 0 to 0.18 mm.

Intense band in blue-green and green. The ultra-violet and visible regions are respectively similar to those of solutions Nos. 95 and 88. All lines near 0.23 and from 0.25 to 0.26μ are freely transmitted. The background indicates a band with its maximum at 0.285 and extending from 0.27 to 0.305μ. Transparent from 0.305 to 0.45 . Very strong absorption from 0.45 to 0.575 with maximum near 0.53 . There are probably two unresolved bands of which the more refrangible is the weaker. Transparent from 0.575μ to 0.63μ . A layer about 1 mm. deep limited the more refrangible, transparent region to the interval from 0.35 to 0.39 .

88. New Magenta. (O.). Hydrochloride of triamido-tritolyl-carbinol.

Fig. 45, plate 12.

No. 449 S. and J.

Beetle green powder.

In solution; red; bluish red.

6.00 g. per liter.

Angle 31'.2. Depth 0 to 0.29 mm.

Strong band in the green, steeper on the yellow side, and suggesting a sharp band superposed upon a weaker one.

This band extends from about 0.44 to 0.56 with its maximum near 0.52 . Transparent from 0.56 to 0.63 .

89. Dahlia. (B.) Mixture of the hydrochlorides or acetates of the mono-di-or tri-methyl (or ethyl) -rosanilines and para-rosanilines.
Fig. 46, plate 12.
No. 450 S. and J.
Green lumpy powder.
In solution; deep blue; reddish violet.
3.57 g. per liter.
Angle 23'.4. Depth 0 to 0.21 mm.

Absorption commences in the blue-green, has its maximum in the green-yellow, and decreases gradually into the red. Transparent to deep red. Absorption in ultra-violet is weak. A band which is definite on the more refrangible edge commences at 0.48 and increases to a maximum at 0.52 . A weak unresolved companion joins the last one near 0.57 and fades away at 0.62 .

90. Crystal Violet. (B.). Hydrochloride of hexamethyl-pararosaniline.
Similar to fig. 49, plate 13.
No. 452 S. and J.
Cantharides glistening crystals.
In solution; violet; violet.

1.38 g. per liter.

Angle 42'.5. Depth 0 to 0.36 mm.

The absorption is the same as that exhibited by solution No. 92, hence see the description given below.

91. Ethyl Violet. (B.) Hydrochloride of hexaethylpararosaniline.

Figs. 47 and 48, plate 12.

No. 453 S. and J.

Green crystalline powder.

In solution; pure deep blue; pinkish blue.

2.73 g. per liter.

Angle 27'.3. Depth 0 to 0.25 mm.

Intense absorption in the green. Very sharp and abrupt on the blue side but indefinite on the red border. Strong lines in the ultra-violet are transmitted pretty freely. Relative transparency in the vicinity of 0.265 . Absorption ceases about 0.31 and from this wave-length to 0.495 transparency obtains. At 0.495 an intense band, having its maximum at 0.525 begins. About 0.585 the absorption becomes relatively weak and diffuse, and continues thus to 0.63 . (A flaw in the plate is responsible for the narrow streak of spurious absorption near 0.62 .)

92. Methyl Violet 6 B. (A.) Chiefly a mixture of the hydrochlorides of benzylpentamethyl-pararosaniline and hexamethylpararosaniline.

Fig. 49, plate 13.

No. 454 S. and J.

Metallic glistening powder.

In solution; blue; reddish blue.

2.50 g. per liter.

Angle 31'.2. Depth 0 to 0.29 mm.

Transmits only blue and pure red in concentrated solution. The solution described below showed two bands, the more intense in the green-yellow, and the weaker in the orange. All strong ultra-violet lines are transmitted. The chief band starts at 0.50 μ, has its maximum at 0.535 , and joins its companion about 0.57 . The weaker band has its maximum at 0.595 and fades away at 0.615 . Transparent from 0.62 to beyond 0.63 .

93. Methyl Green 00. (By.) Zinc-double-chloride of heptamethyl-pararosaniline-chloride.

Similar to fig. 50, plate 13.

No. 460 S. and J.

Green crystals.

In solution; greenish blue; greenish blue.

6.00 g. per liter.

Angle 19'.5. Depth 0 to 0.18 mm.

Band in violet and blue, also strong absorption in orange and red. The band in the orange is partly separated from the stronger band whose intensity increases to, and beyond 0.63 . With due allowance for differences in concentration, it appears that the absorption is, in toto, the same as that shown by solution No. 94. Absorption decreases from 0.20 to a region of less intense absorption at 0.28 . Then follows a strong band with maximum at 0.315 . A band from 0.375 to 0.445 has its maximum at 0.415 . The yellow and orange band begins at 0.515 .

94. Methyl Green. Zinc-double-chloride of ethyl-hexamethyl-pararosaniline bromide.

Fig. 50, plate 13.

No. 461 S. and J.

Moss-green crystalline powder.

In solution; bluish green; bluish green.

20.00 g. per liter.

Angle 19'.5. Depth 0 to o.18mm.

Band in violet and blue, also strong absorption in orange and red. Transmits green and yellow-green. Band from 0.36 to 0.45 with maximum at 0.415 . This band is steeper on its green side. Very transparent from 0.45 to 0.495 . From 0.495 the absorption is intense and no return to trans-

parency can be seen at 0.63 . The band at 0.415 disappears first on dilution.

95. Fuchsine S. (B.) Mixture of the sodium or ammonium salts of the trisulphonic acids of rosaniline and pararosaniline.

Fig. 51, plate 13.

No. 462 S. and J.

Metallic green glistening powder.

In solution; red; red.

3.00 per liter.

Angle 23'.4. Depth 0 to 0.21 mm.

Strong absorption in the blue-green and green. The middle of the first transparent region is about 0.265 . A weak absorption band has its maximum near 0.295 . The visible band commences at 0.475 , has its maximum about 0.535 , and ends at 0.575 . Transparent from 0.575 to 0.63 .

96. Red Violet 5 R. S. (B.) Sodium salt of ethylrosanilinesulphonic acid.

Fig. 52, plate 13.

No. 463 S. and J.

Brownish violet, metallic glistening lumps.

In solution; brownish red; brownish red.

Saturated .

Angle 58'.5. Depth 0 to 0.54 mm.

General absorption in the green, yellow and orange. The ultra-violet absorption is complete from 0.20μ to 0.36μ . Absorption decreases gradually from 0.36μ to a minimum of general absorption near 0.47μ . A weak band has its maximum about 0.525μ . The marked slant of the end of the negative shows the presence of appreciable general absorption in the yellow and orange. Red is transmitted.

97. Alkali Blue 6 B. (A.A.C.) Sodium salt of triphenyl-p-rosaniline-monosulphonic acid.

Fig. 53, plate 14.

No. 476 S. and J.

Blue powder.

In solution; blue; delicate blue.

12.50 g. per liter, (heated).

Angle 23'.4. Depth 0 to 0.21 mm.

Strong absorption in yellow, orange and red. Intense, continuous absorption from 0.20μ to 0.32 . Abrupt decrease in absorption from 0.32 to transparency at 0.345 . Transparent from 0.345 to 0.51 . Strong absorption from 0.51 to beyond 0.53 . No decrease in absorption as far as 0.63 The apparent increase in absorption near 0.62 is due to the

relative diminution of sensitiveness of the photographic emulsion.

98. Methyl Blue. (O.) Sodium salt of triphenyl-pararosaniline-trisulphonic acid.
Similar to fig. 54, plate 14.
No. 479 S. and J.
Dark blue powder.
In solution; deep bright blue; true blue.
6.89 g. per liter.
Angle 21'.3. Depth 0 to 0.18 mm.

Strong absorption in the yellow, orange and red. The description for solution No. 99 holds here quantitatively.

99. China Blue. (A.) Sodium salt of the trisulphonic acid of triphenylrosaniline and triphenylpararosaniline.
Fig. 54, plate 14.
No. 480 S. and J.
Coppery flakes.
In solution; pure blue; blue.
3.57 g. per liter, (filtered).
Angle 23'.4. Depth 0 to 0.21 mm.

A hazy-edged band begins in the green and continues into the red. The strong lines around 0.255μ are transmitted by the deepest layer of liquid. Absorption is more or less uniform from 0.20 to 0.32 and then shades off to transparency at 0.345

Transparent from 0.345 to 0.505 . Then a band starts and continues with undiminished intensity to 0.63 .

100. Coralline Red. Dioxy-amido-triphenylcarbidrid.

Fig. 55, plate 14.

No. 484 S. and J.

Reddish brown lumps.

In solution; red; salmon pink.

11.25 g. per liter, (heated).

Angle 19'.5. Depth 0 to 0.18 mm.

Sharp band in blue and green. Very definite at yellow side with maximum in green-yellow. Rather strong absorption from 0.20 to 0.27μ, then a decrease to transparency at 0.315 . Strong absorption from 0.445 to 0.557 with maximum at 0.527μ. Probably two unresolved bands with the weaker component at the more refrangible side. Transparent from 0.557 to 0.63μ.

101. Night Blue. (B.) Hydrochloride of p-tolyltetraethyl-triamido-diphenyl-α-naphthyl-carbinol.

Similar to fig. 56, plate 14.

No. 489 S. and J.

Violet bronzy powder.

In solution; bright blue; blue.

2.31 g. per liter.

Angle 23'.4. Depth 0 to 0.21 mm.

Absorption in the yellow, orange and red. The limit at the green side is steep and the curve is flat in the longer wave-lengths. The visible region of absorption begins about 0.525 . For the ultra-violet absorption see fig. 56.

102. Victoria Blue. 4 R. (B.) Hydrochloride of phenylpentamethyl-triamido-di-phenyl-a-naphthol-carbinol.

Fig. 56, plate 14.

No. 490 S. and J.

Bronzy glistening powder .

In solution; deep blue; reddish blue.

2. 8 g. per liter, (heated).

Angle 27'.3. Depth 0 to 0.25 mm.

Hazy-edged absorption in yellow and orange. The red is only partially absorbed. Comparatively weak absorption decreases steadily from 0.20μ to about 0.335μ . A band commences at 0.495μ and continues to a maximum at 0.53μ . From this point the band shades off gently towards the red. (The apparent increase of absorption at 0.62 is probably due to the increasing lack of sensitiveness of the plate.)

103. Rhodamine B. (B.) Hydrochloride of diethyl-m-amido-phenol-phthalene.

Figs. 57 a and 57 b, plate 15.

No 504 S. and J.

Reddish violet powder.

In solution; bluish red, violet.

7.50 g. per liter.

Angle 42'.5. Depth 0 to 0.36 mm.

Two distinct bands, the one in the yellow-orange and the other in the green-yellow. Eye observations, changes in concentration, and different makes of films show that the more refrangible band is the more intense. Fluorescent solution. Absorption decreases gradually from 0.20 to an indefinite limit near 0.32 . Strong absorption from 0.494 to about 0.59 . The maxima are at 0.524 and 0.557 with the intervening minimum of absorption at 0.54 . Transparent beyond the orange band into the red.

104. Fast Acid Violet B. (M.) Sodium salt of diphenyl-m-amido-phenolphthalein sulphonic acid.

Somewhat like fig. 58, plate 15.

No. 506 S. and J.

Maroon powder.

In solution; bluish red; pink.

3.33 g. per liter.

Angle 27'.3. Depth 0 to 0.25 mm.

Absorption band in the green-yellow. This band is comparatively definite on the green side and has a shadowy com-

panion on the red side. General absorption continues well into the orange-red. All strong lines in the ultra-violet are transmitted. The ultra-violet absorption ends about 0.33 μ . The visible band begins at 0.505 μ and has its maximum near 0.53 μ . The less refrangible limit is indeterminate. The essential difference between the spectrograms for solutions Nos. 104 and 106 is that for the former the visible band is asymmetric whereas for the latter it is symmetric.

105. Fast Acid Violet A 2 R. (M.) Sodium salt of di-o-tolyl-*m*-amido-phenol-phthalein-sulphonic acid.

Similar to fig. 58, plate 15.

No. 507 S. and J.

Violet red powder.

In solution; red; pink.

4.67 g. per liter.

Angle 23'.4. Depth 0 to 0.21 mm.

Very narrow, definite band in the green. All strong ultra-violet lines are transmitted. The ultra-violet absorption ends about 0.355 μ . The visible band begins at 0.495 μ , has its maximum at 0.525 μ , and ends near 0.57 μ . The slanting end of the spectrogram indicates general absorption in the deep yellow. The green band for this solution is of the same type as the corresponding one for No. 104 only it is much less

asymmetric, and therefore it resembles more closely No. 106. Solutions Nos. 104 and 105 have the same empirical formulae.

106. Acid Rosamine A. (A.) Sodium salt of di-mesidyl-m-amido-phenolphthalein-sulphonic acid.

Fig. 58, plate 15.

No. 508 S. and J.

Light red powder.

In solution; red; pink.

10.00 g. per liter.

Angle 29'.3. Depth 0 to 0.27 mm.

Single V-shaped band in the green. Weak absorption beginning with extinction at 0.20 μ and fading gradually to transparency at 0.32 μ. An absorption band covers the interval from 0.505 to 0.565 with its maximum at 0.535. Transparent from 0.565 to 0.63.

107. Uranine. (B.) Sodium or potassium salt of fluoresceïne.

Figs. 59, 60 and 61, plates 15 and 16.

No. 510 S. and J.

Yellowish brown powder.

In solution; reddish yellow; yellow.

Intense, narrow band in the blue-green with a weaker companion on its more refrangible side. Very strong, yellowish green fluorescence.

Figure 59 resulted from a solution of 2 g. per liter.

Angle 23'.4. Depth 0 to 0.21 mm . Only the stronger band shows. Here it extends from 0.480 to 0.504 with its maximum at 0.493 .

Figure 60 corresponds to 2.67 g. per liter. The angle 31.'2 gives 0.58 mm. and 0.96mm. respectively for the depths to which the outer edges of the sixth* and tenth photographic strips correspond. The spectrogram shows that the visible region of absorption has roughly parallel sides which are very definite and approximately straight lines. The visible maximum is at 0.493 as before. At the outer edge of the sixth strip the absorption covers the interval from 0.437μ to 0.515 .

Figure 61 was obtained from a solution of 5 g. per liter. Angle 42'.5. Depth 0 to 0.36 mm. Visible absorption from 0.432 to 0.518 with the maximum at 0.493 .

A solution of 20 g. per liter with an angle of 42'.5 caused the ultra-violet and visible absorption bands to coalesce on the third photographic strip in a semi-transparent region extending roughly from 0.355 to 0.395 . Intense absorption from 0.395 to 0.533 . The short wave-length boundary is indefinite but the opposite limit is very sharply defined and steep. Maximum absorption at 0.493 .

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* The spectrogram indicates that something happened to the cell between the taking of the sixth and seventh strips.

Tests were made to ascertain whether or not the conditions were favorable to contamination of the absorption spectra by the fluorescent light. The most dilute solution was illuminated with intense ultra-violet light and an exposure of five minutes was given to the photographic film. Full development of the film brought out no trace of previoulsy incident light. Therefore, since the Nernst glower alone was used in making the records of the visible bands and because, in all cases except one, more concentrated solutions were used, it follows that the spectrograms are correct representations of the absorption, at least, so far as the fluorescent light is concerned.

108. Eosine, yellowish. (A.) Alkali salts of tetrabromofluoresceïne.

Similar to fig. 63, plate 17.

No. 512 S. and J.

Deep red powder.

In solution; yellowish red; pink.

20.00 g. per liter.

Angle 21'.3. Depth 0 to 0.18 mm.

Very strong absorption in blue and green. Faint green fluorescence increasing with dilution. Similar absorption to that ofsolution No. 111. Intense absorption from 0.20μ to 0.33μ . The absorption then decreases first gradually

and then steeply to partial transparency at 0.37μ. This transparent region continues as far as 0.434μ. Intense absorption from 0.434μ to 0.56μ. From 0.515μ to 0.525μ the solution is almost opaque. Two unresolved bands seem to be present. The more refrangible boundary of the visible absorption is less definite than the opposite side. The latter limit is steep and sharp. Transparent from 0.56 to 0.63

109. Eosine à l'alcool. (B.) Potassium salt of tetrabromo-fluoresceïne-ethyl-ether.

Fig. 62, plate 16.

No. 514 S. and J.

Brown powder mixed with small green crystals.

In solution; red; pink.

4.29 g. per liter, (heated).

Angle 46'.8. Depth 0 to 0.43 mm.

Sharp, narrow band in green, abrupt on yellow side and diffuse on the blue side due to a faint companion band. Slight greenish yellow fluorescence. Very weak absorption in extreme ultra-violet. Absorption begins at 0.495μ and ends at 0. 540μ. The chief maximum is at 0.525μ. Transparent from 0.540μ to 0.63μ.

110. Methyl Eosine. (A.) Potassium salt of dibromodinitrofluoresceïne.

Similar to fig. 63, plate 17.

No. 515 S. and J.

Brown crystalline powder.

In solution; red; orange.

10.00 g. per liter.

Angle 15'.6. Depth 0 to 0.14 mm.

Intense band in blue and green. Apparently two unresolved bands. Similar absorption to that of solution No. 111. Absorption is rather complete from 0.20μ to 0.3μ and then decreases to about 0.36μ. Strong absorption from 0.46μ to 0.56μ. The principal maximum is at 0.52μ. Very transparent from 0.56μ to 0.63μ.

111. Eosine, bluish. (B.) Sodium salt of tetraiodo-fluoresceïne.

Fig. 63, plate 17.

No. 517 S. and J.

Lavender powder.

In solution; red; pink.

15.00 g. per liter.

Angle 21'.3. Depth 0 to 0.18 mm.

Intense absorption in the blue-green. The yellowish green fluorescence only appears in dilute solutions. Absorption

decreases gradually from 0.20μ to 0.36μ . Intense absorption from 0.455μ to 0.555μ. Maximum of absorption at 0.52μ . There seem to be two unresolved bands of which the more refrangible is a little less intense than its companion. This region of absorption is sharper and steeper at its yellow border. Transparent from 0.555μ to 0.63μ .

112. Erythrosine. (M.) Sodium salt of tetraiodo-fluoresceine.

Fig. 64, plate 17.

No. 517 S. and J.

Dark red powder.

In solution; red; pink.

15.00 g. per liter.

Angle 21'.3. Depth 0 to 0.18 mm.

Intense absorption in the blue and green. A strong band in the middle with a slightly weaker, unresolved companion on each side. The yellowish-green fluorescence only appears in dilute solutions. The region of visible absorption is from 0.455μ to 0.568μ . The chief maximum is about 0.518μ . The yellow edge of this group of bands is very sharply defined. Transparent from 0.562μ to 0.63μ .

113. Cyanosine. (M.) Alkalino salt of tetrabromodichloro-fluoresceine-methyl-ether.

Fig. 65, plate 17.

No. 519 S. and J.

Brownish red powder.

In solution; red; bluish pink.

Saturated, (boiled).

Angle 25.'4 . Depth 0 to 0.23 mm.

Band in blue-green and green. Faint yellowish fluorescence. Strong absorption from 0.493μ to 0.553μ with its maximum at 0.525μ . Transparent from 0.553μ to 0.63μ .

114. Rose Bengal. (B.) Alkaline salt of tetraiododi-chlorofluoresceïne.

Fig. 66, plate 17.

No. 520 S. and J.

Brown powder.

In solution; red; orange.

15.00 g. per liter.

Angle 21'.3. Depth 0 to 0.18 mm.

Double, unresolved pair of bands in green. In amyl alcohol the bands were nearly resolved. Strong absorption from 0.48μ to 0.575μ . Transparent from 0.575μ to 0.63μ .

115. Phloxine. (B.) Sodium salt of tetrabromotetra-chlorofluoresceïne.

Fig. 67, plate 18.

No. 521 S. and J.

Brick red powder.

In solution; cherry red; pink.

12.50 g. per liter.

Angle 42'.5. Depth 0 to 0.36 mm.

Intense absorption in the green. Dark green fluorescence. The visible band lies between 0.458μ and 0.57 . The maximum is near 0.525 . For dilute solutions the absorption is very much like that shown by fig. 65, except that the contour of the band in the green is sharper than for solution No. 113.

116. Galleïne. (By.) Pyrogallol-phthalein.

Similar to fig. 29, plate 8.

No. 525 S. and J.

Violetbrown powder.

In solution; very darkbrown; brown.

Saturated, (heated).

Angle 58'.5. Depth 0 to 0.54 mm.

Hazy-edged absorption in the blue-green and green. The absorption is comparatively strong at 0.20 and decreases very gradually to semi-transparency about 0.435 . Only partial transparency exists between 0.435 and 0.485 . A V-shaped band absorbs from 0.485μ to 0.553μ. The maximum is about 0.52μ. The end of the negative slants a good deal showing general absorption in the yellow-orange. The spectrogram is like that which would be obtained with a more

concentrated solution of No. 47 if it were possible to produce such a condition.

117. Phosphine. (M.) Nitrate of chrysamiline(unsym.di-amido-phenyl-acridine), and homoloques.

Fig. 68, plate 18.

No. 532 S. and J.

Orange yellow powder.

In solution; brown; yellow.

11.25 g. per liter, (heated and filtered).

Angle 27'.3. Depth 0 to 0.25 mm.

Absorption in violet, blue and green with hazy limits. Strong absorption from 0.20μ to 0.295μ, then weakening to semi-transparency at 0.335μ. Next a band with maximum at 0.36μ. Return to partial transparency at 0.41μ. Then follow two unresolved bands with maxima about 0.458μ and 0.50μ. Complete transparency from 0.52μ to 0.62μ. A solution so concentrated as to absorb all the ultra-violet and visible spectrum from 0.20μ to 0.538μ was transparent to 0.63μ.

118. Alizarine Brown .(M.) Trioxyanthre-quinone.

Similar to fig. 29, plate 8.

No. 538 S. and J.

Dark brown powder.

In solution; dull brown; brown.

Saturated.

Angle 35'.1. Depth 0 to 0.32 mm.

General, indefinite absorption except in the red. Absorption intense and uniform from 0.20 to 0.33 . From 0.33 the absorption decreases very gradually and nearly linearly to about 0.47 . A very weak band with its maximum at 0.52 exists over and above the intensity minimum of the sensitized film. The end of the negative slopes appreciably denoting continued general absorption in the orange. No visible weakening of the red. A maximum of transparency is around 0.48 μ. The spectrograms for solutions Nos. 116 and 118 are very similar.

119. Alizarine Red S. (B.) Sodium salt of alizarine-monosulphonic acid.

Fig. 69, plate 18.

No. 546 S. and J.

Orange yellow powder.

In solution; reddish yellow; yellow.

12.00 g. per liter, (heated and filtered).

Angle 30'.0. Depth 0 to 0.45 mm.

Absorption in violet and blue. Opaque from 0.20 to 0.275 . Absorption decreases gradually from 0.275 to partial transparency at 0.377 and then increases to a maximum at 0.42 . Absorption ends at 0.485 . No visible absorption from 0.49 to 0.63 μ.

120. Alizarine Blue S. (B.) Sodium bisulphite compound of dioxy-anthra-quinone-β-quinoline.

Fig. 70, plate 18.

No. 563 S. and J.

Chocolate brown powder.

In solution; yellowish brown; brown.

7.37 g. per liter.

Angle 58'.5. Depth 0 to 0.54 mm.

Absorption in violet, blue and green. The absorption extends into the ultra-violet. Absorption from 0.20μ to 0.33μ is almost complete save a slight weakening around 0.285μ. Intense maximum at 0.315μ. Absorption decreases abruptly from beyond 0.33μ to transparency at 0.36μ. The transparent region is from 0.36μ to about 0.385μ. A pair of wide bands absorb from 0.385μ to 0.543μ. Their maxima are at 0.44μ and 0.517μ. The intervening minimum of absorption is at 0.48μ. Transparent from 0.543μ to 0.63μ. The ultra-violet bands remain very intense even when dilution causes the visible bands to disappear.

121. Neutral Red. (D.H.) Hydrochloride of dimethyldiamidotoluphenazine.

Similar to fig. 71, plate 19.

No. 580 S. and J.

Dark green powder.

In solution; red; pink.

3.00 g. per liter.

Angle 39'.0. Depth 0 to 0.36 mm.

Band in blue and blue-green, not sharp at edges. Very similar absorption to that of solution No. 122. Slight transparency at 0.23μ. A band lies between this point and 0.31μ where transparency begins to be complete. An absorption band extends from 0.468μ to 0.545 with its maximum at 0.507μ. Transparent from 0.545 to 0.63μ.

122. Phenosafranine. Diamidophenyl-phenazonium chloride.

Fig. 71, plate 19.

No. 583 S. and J.

Green glistening crystals.

In solution; clear red; pink.

2.50 g. per liter.

Angle 39'.0. Depth 0 to 0.36 mm.

Band in blue and blue-green, not sharp at edges. The ultra-violet band ends about 0.31μ. The visible band absorbs from 0.45 to 0.545μ with maximum at 0.50μ. Transparent from 0.545μ to 0.63μ.

123. Safranine. (B.) Mixture of diami-do-phenyl-and tolyl-tolazonium chlorides.

Similar to fig. 71, plate 19.

No. 584 S. and J.

Reddish brown powder.

In solution; red; red.

5.00 g. per liter.

Angle 27'.3. Depth 0 to 0.25 mm.

Definite absorption in blue-green and green. Similar absorption to that of solution No. 122. Strong absorption from 0.20 μ to 0.28 μ. Rapid decrease in absorption from 0.28 μ to 0.32 μ. Absorption begins again at 0.44 μ, increases to a maximum near 0.495 μ, and then decreases to transparency at 0.555 μ. Transparent from 0.555 μ to 0.63 μ.

124. Heliotrope 2 B. (A.) Dimethyldiamido-xylyl-xylophenazonium chloride.

Fig. 72, plate 19.

No. 590 S. and J.

Grayish green powder.

In solution; reddish violet; reddish violet.

7.00 g. per liter.

Angle 27'.3. Depth 0 to 0.25 mm.

Strong band in yellow and orange. Transparent to deep red. Strong absorption from 0.48 μ to 0.605 μ with maximum near 0.535 μ. Increasing transparency from 0.605 μ into the red.

125. Rosolane O. (M.) Phenyldiamido-phenyl-toluphen-azonium chloride.

Similar to fig. 58, plate 15.

No. 591 S. and J.

Olive green powder.

In solution; deep violet; faint reddish violet.

9.00 g. per liter, (warmed and filtered).

Angle 35'.1, Depth 0 to 0.32 mm.

Weak band in the green broadening out into general absorption on the red side. Somewhat similar absorption to that of solution No. 106. Slight transparency at 0.23 μ is followed by a maximum of absorption near 0.27 μ. Absorption ceases about 0.33 μ and begins again at 0.495 μ. The latter band has its maximum at 0.525 μ and fades into general absorption around 0.563 μ. The end of the positive slants appreciably thus emphasizing the general absorption in the orange. Transparent to the red.

126. Nigrosine, soluble. (A.) Sodium salts of sulphonic acids of spirit nigrosines.

No. 602 S. and J.

Coal black glistening lumps.

In solution; blackish blue; dull blue.

Saturated.

Angle 31'.2. Depth 0 to 0.29 mm.

Very indefinite absorption in the yellow and orange. Absorption rather strong between 0.20μ and 0.30μ. From 0.30μ the absorption decreases to transparency at 0.35μ. Different photographic emulsions show a weak band about 0.528μ. Absorption continues general into the red as is shown by the appreciable slant of the end of the negative.

127. Naphthalene Red. Mixture of amido-naphthyl-naphthazonium chloride and diamido-naphthyl-naphthazonium chloride.

Fig. 73, plate 19.

No. 614 S. and J.

Dark brown powder.

In solution; red; faint pink.

Saturated, (heated).

Angle 31'.2. Depth 0 to 0.29 mm.

Hazy-edged absorption band in the green. The visible band extends from 0.488μ to 0.545μ with its maximum at 0.517μ. The slight inclination at the red end of the negative shows appreciable decrease of transparency, between 0.545μ and 0.63μ with increase of thickness of absorbing layer.

128. Alizarine Green B. (D.) Dioxynaphth-azoxonium sulphonate.

No. 647 S. and J.

Dark green powder.

In solution; dark green; light green.

20.00 g. per liter, (heated and filtered.)

Angle 31'.2. Depth 0.20 to 0.55 mm.

General absorption in the violet, orange and red. The minimum of absorption lies in the green, of course. When the depth was 0 to 0.29mm., the ultra-violet absorption ended at about 0.355 μ. There is no sharp band in the ultra-violet, but simply one-sided absorption decreasing from 0.20 μ towards the longer wave-lengths.

129. Columbia Yellow. (A.) Oxidation-products of dehydrothioto-luidine-sulphonic acid or of the latter and primuline together.

Fig. 74, plate 19.

No. 665 S. and J.

Brownish yellow powder.

In solution; yellow; light yellow.

10.00 g. per liter, (warmed).

Angle 31'.2. Depth 0 to 0.29 mm.

Weak-edged absorption in violet. Uniform absorption from 0.20 μ to about 0.36 μ. Then a steady decrease in absorption to 0.45 μ. Complete transparency from 0.45 μ to 0.63 μ.

130. Quinoline Blue.(G.)

No. 664 S. and J.

Glistening green crystals.

In solution; delicate violet; pink.

Saturated, (heated).

Angle 0 . Depth 134 to 134 mms.

Only the blue and blue-green faintly transmitted. (No photograph was taken for the saturated solution.) When 44 c.c. of the saturated solution was diluted to 90 c.c. a strong band appeared in the yellow and orange, while the red was freely transmitted. The ultra-violet absorption extends to 0.40μ and fades out about 0.42μ . Weak absorption begins at 0.48 and increases to opacity near 0.55μ . Complete absorption continues to about 0.607μ . Absorption decreases rapidly from 0.607μ to 0.63μ . When 44 c.c. of the saturated solution was made up to 112 c.c. and a column 15 cms. was used, no definite band could be seen but only a faint weakening of the orange. The ultra-violet absorption was, however, complete as far as 0.374μ and vanished near 0.395μ .

131. Quinoline Yellow, soluble in water.(A.) Quinoline Yellow O.(M.) Sodium salt of the sulphonic acid (chiefly disulphonic acid) of quinophthalone.

Fig. 75, plate 20.

No. 667 S. and J.

Yellow powder.

In solution; lemon yellow; faint yellow.

17.50 g. per liter.

Angle 27'.3. Depth 0 to 0.25 mm.

Strong band in extreme violet. One-sided absorption in ultra-violet ends about 0.33 μ. Transparent region from 0.33 μ to 0.345 μ. A band commences at 0.345 μ, has its maximum at 0.40 μ and joins a narrow companion band at 0.438 μ. Maximum of little band is about 0.448 μ and complete transparency extends from 0.453 μ to 0.63 μ. For a five-strip negative the absorption only advanced to 0.463 μ.

132. Indigo Carmine, dry. Sodium salt of indigotine disulphonic acid.

No. 692 S. and J.

Deep violet powder.

In solution; blue; blue.

10.00 g. per liter.

Angle 23'.4. Depth 0 to 0.21 mm.

Transmits green and yellow. Moderately intense band in the orange red beginning about 0.555 μ and increasing beyond 0.63 μ. General absorption from 0.20 μ to complete transparency at 0.37 μ.

133. Acid Magenta S. (A.)

Similar to fig. 51, plate 13.

Dark green powder.

In solution; bluish red; bluish pink.

10.00 g. per liter.

Angle 15'.6. Depth 0 to 0.14 mm.

Strong band in the green with abrupt edges. Violet, indigo, orange and red are transmitted. Similar absorption to that of solution No. 95. Partial transparency in the vicinity of 0.265 μ. A comparatively weak, narrow band has its maximum near 0.295 μ, and absorption ceases about 0.325 μ. An intense region of absorption begins at 0.46 μ, has its maximum at 0.535 μ, and ends at 0.58 μ. Therefore, this region slants more at the violet border than at the orange side. The band is very smooth and round.

134. Alizarine Orange. (Powder 80%.) (M.)

Fig. 76, plate 20.

Very deep purple powder.

In solution; dark red; red.

5.83 g. per liter, (warmed and filtered).

Angle 27'.3. Depth 0 to 0.25 mm.

Weak, shadowy band in the green-yellow gradually fading away in the red. The ultra-violet absorption is intense and one-sided, and ceases about 0.39 μ. The visible band begins near 0.48 , has its maximum at 0.525 , and fades into general absorption about 0.56 . The end of the negative slopes to an unusual extent showing that the general absorption is relatively strong.

135. Alizarine Red No. 1, 40%. (M.)

Similar to fig. 29, plate 8.

Yellow paste.

In solution; deep yellow; yellow.

Saturated.

Angle 31'.2. Depth 0 to 0.29 mm.

Absorption very weak, general and indefinite. A few mms. of the solution show complete opacity. The solution looks like a milky but yellow emulsion. The ultra-violet absorption is relatively weak, is quite general, and fades away to semi-transparency near 0.4 μ. A slight weakening of transparency around 0.52 may be the fault of the sensitized film. The end of the negative slopes quite enough to indicate continued absorption in the orange. No visible absorption in the red.

136. Aurophosphine 4 G. (A.)

Fig. 77, plate 20.

Reddish brown powder.

In solution; clear yellow; yellow.

11.67 g. per liter.

Angle 27'.3. Depth 0 to 0.25 mm.

Strong absorption in the violet and indigo. Absorption decreases from 0.20μ to a maximum at 0.245μ and then follows a rounded curve to transparency at 0.305μ. Unusual transparency from 0.305μ to 0.390μ. As for p.nitrosodimethyl aniline, so here, all the strong lines between 0.324μ and 0.363μ are transmitted with almost no decrease in intensity. A V-shaped band absorbs from 0.390μ to 0.470μ with its maximum at 0.430μ. Transparent from 0.470μ to 0.63μ.

137. Brilliant Croceïne, blue shade. (M.)

Similar to fig. 17, plate 4.

Bright red powder.

In solution; red; salmon pink.

7.00 g. per liter.

Angle 25'.4. Depth 0 to 0.25 mm.

Strong band in blue-green and green. It slopes more on the blue than on the yellow border. Similar absorption

to that of solutions Nos. 21 and 43. Absorption decreases from 0.20 to a region of partial transparency in the vicinity of 0.29 . A symmetrical hazy band absorbs from about 0.305 to 0.385 . A strong band absorbs from 0.458 to 0.558 with its maximum near 0.518 μ. Transparent to the orange and red.

138. Brilliant Purpurine 10 B. (A.)

Similar to fig. 28, plate 7.

Grayish violet powder.

In solution; red; bluish red.

5.83 g. per liter, (warmed).

Angle 23'.4. Depth 0 to 0.21 mm.

Shadowy band in the green with general absorption in the yellow and orange. Similar absorption to that of solution No. 46. Absorption decreases from 0.20μ to a semi-transparent region around 0.29μ. A symmetrical hazy band absorbs from about 0.30μ to 0.38μ. Another band begins near 0.48μ, has its maximum at 0.52μ, and ends at 0.555μ. The end of the negative slants at an angle of about 30° thus emphasizing the strong, general absorption in the yellow-orange.

139. Columbia Fast Scarlet 4 B. (A.)

Fig. 37, plate 10.

Red powder.

In solution; yellowish red; pink.

5.83 g. per liter.

Angle 27'.3. Depth 0 to 0.25 mm.

Broad absorption in the blue, blue-green and green. The contour is somewhat hazy. The spectrogram is identical with fig. 37 for solution No. 67.

140. Dianil Orange G. (M.)

Fig. 78, plate 20.

Brick red glistening powder.

In solution; yellowish red; yellow.

11.67 g. per liter.

Angle 23'.4. Depth 0 to 0.21 mm.

Uniform absorption from the blue border of the green to the extreme violet and beyond. Except for slight, wavy regions, the absorption decreases almost linearly from 0.20 µ to about 0.53 µ. At this point it ends rather abruptly. Transparent from 0.53 µ to 0.63 µ.

141. Fluoresceïne. Tetraoxyphtalo-phenom anhydride $C_2 H_2 O_5$ + H_2O.

Cinnibar red powder.

In solution; faint yellow.

Saturated, (boiled).

Angle 0°. Depth 3.7 to 3.7 mms.

Weak band in blue and blue-green. Intense green fluorescence. Absorption complete from 0.20μ to 0.25μ and then decreases to transparency at 0.29μ . Weak absorption extends from about 0.46μ to 0.505μ .

142. Guinea Carmine B. (A.)

Fig. 79, plate 21.

Brown powder.

In solution; red; pink.

Saturated.

Angle 2° 17'. Depth 0.26 to 1.51 mms.

Absorption in green. No lines transmitted between 0.20μ and 0.273μ . (Non-zero depth of liquid). A hazy-edged band extends from 0.493μ to 0.548μ with its maximum at 0.521 . Transparent from 0.548μ to 0.63μ .

143. Soluble Prussian Blue.

Deep blue, glistening powder.

In solution; deep blue; blue.

1.76 g. per liter.

Angle 21'.3. Depth 0 to 0.18 mm.

Strong absorption in the yellow, orange and red. Almost opaque from 0.20μ to 0.28μ . Absorption decreases very gradually from 0.28μ to 0.38μ . The visible region of absorption begins at 0.505 and continues to 0.63μ and beyond.

144. Thiogene Brown S. (M.)

Similar to fig. 29, plate 8.

Bluish black lumps.

In solution; dull brown; brown.

Saturated.

Angle 27'.3. Depth 0 to 0.25 mm.

General weakening of all the visible spectrum except the blue and red. The solution smells strongly of hydrogen sulphide. (The odor is not so marked for the dry dye.) Similar absorption to that of solution No. 47. Absorption decreases very gradually from 0.20μ to about 0.41μ. On both sides of 0.445μ the absorption is at a minimum. A very shadowy band absorbs from 0.49μ to 0.545μ. Its maximum is near 0.523μ. The end of the negative slants markedly and thus points to the absorption in the yellow and orange.

145. Thiogene Orange. R. (M.)

Similar to fig. 21, plate 5.

Brown powder.

In solution; reddish brown; yellow.

5.83 g. per liter, (filtered).

Angle 50'.7. Depth 0 to 0.46 mm.

Weak absorption in the violet. The solution has an unpleasant odor. Its absorption is similar to that of solution No. 30. Absorption is complete from 0.20 μ to 0.25 μ and then decreases with a long, gentle curve to transparency about 0.445 μ. Transparent from 0.445 μ to 0.63 μ.

MISCELLANEOUS ABSORBING MEDIA.

146. Aesculine.

Figs. 80 and 81, plate 21.

White powder.

In solution; colorless.

Saturated.

Angle 39'.0. Depth 0 to 0.36 mm.

No visible absorption. Intense blue fluorescence. Absorption decreases from 0.20 μ to semi-tranparency about 0.26 μ. Partial transparency from 0.26 μ to 0.273 μ. The band with which the fluorescence is probably associated extends from 0.273 μ to 0.363 μ with its maximum near 0.32 μ. Complete transparency from this band to 0.63 μ and beyond. Figure 81 shows the results of using copper electrodes instead of Cd-Zn-brass.

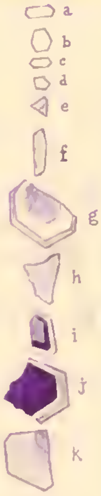
147. Barium Permanganate.

The absorption is identical with that of potassium permanganate solutions having the same concentration in the M_nO_4 ions. *See* No. 152.

148. Carborundum and Diamond. *

Fig. 82**, plate 21.

Eight crystalline plates of carborundum and three of diamond were fastened to a strip of black paper in such a manner as to bridge across different parts of a long, slit-like opening in the paper. The carborundum plates varied in color from visible transparency to deep blue. The carbons were colorless. The accompanying sketch shows approximately the size, shape, relative positions, and distribution of blue, of the plates. d, e and f denote the diamonds. The paper strip was slid over the slit of the spectrograph, parallel to the length of this opening, and successive exposures were taken. The absorption produced by plates a,b,c,d and e was first photographed, then the absorption of f and g , next



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* Kindly loaned by Mr. L. E. Jewell.

** Due to the manner in which the photograph is numbered the wave-lengths increase from right to left.

that of h and i, and lastly, that of j and k. The spark and glower exposures were, as usual, 75 secs. and 60 secs. respectively.

Plate a was uniformly colored a blue of moderate intensity . Its absorption is shown by the photographic strip the outer boundaries of which are numbered 1 and 2. In cases where the crystals were not in contact the light passed through between them and produced narrow comparison spectra; for example, the strip between Nos. 2 and 3.

Plate b was almost colorless with a frosted surface. Thickness 0.036 mm. Its absorption spectrum is the strip between 3 and 4.

Plate c had about the same color as plate a. Thickness 0.173 mm. Its absor-tion spectrum is the strip between 5 and 6.

Plate d was a smooth, colorless carbon. Thickness 0.191 mm. Its spectrum is between 6 and 7. c and d were practically in contact. This pair of plates show how much more transparent to ultra-violet light pure carbon is than a colorless plate of carborundum of comparable thickness. Judging by the negative the former transmits no light of wave-length shorter than 0.273 μ, whereas the latter absorbs everything shorter than 0.39 μ.

Plate e had such an irregular surface that the light transmitted by it did not fall upon the sensitized film. Thickness about 0.191mm. The blank between 10 and 11 is due to the translation of the photographic film between the first and second settings.

Plate f was a diamond with irregularities running parallel to the slit. Thickness 0.533 mm. Spectrum between 11 and 12.

Plate g was a deeper blue than any of the above mentioned crystals in the pentagon nearer plate f. The wide border extending around four sides of the blue area was practically colorless. Thickness 0.602 mm. Spectrum between 13 and 14. f and g contrast diamond, colorless carborundum and blue carborundum with one another. The blank from 14 to 15 marks the second setting of the film.

Plate h had a delicate, uniform, blue tint. Thickness 0.064 mm. Spectrum between 16 and 17.

Plate i was a deeper blue than any of the preceding crystals. Thickness 0.345 mm. Spectrum between 18 and 19. The blank from 19 to 20 corresponds to the third setting of the photographic film.

The centre of plate j was as deep in color as the middle of i and it was also the thickest plate studied. Thickness

0.693 mm. Spectrum between 20 and 21.

Plate k was of a delicate blue color of a slightly deeper hue than plates b and c except in the corner nearer j. In the latter place it had about the same tint as plate h. Thickness 0.097 mm. Spectrum between 22 and 23.

149. Diamond.

See No. 148.

150. Ethyl Alcohol.

Figure 83, plate 22.

A cell was filled, to a depth of 13.5 mms., successively with 95% alcohol, with glycerine, and with distilled water. Each exposure lasted for 1.5 minutes. The middle strip of figure 83 corresponds to the glycerine and the strip showing no absorption at all resulted from the light transmitted by the water. The alcohol absorbed all light of wave-length less than 225μ and showed a general weakening of the continuous background as far as about 0.28μ.

The corresponding wave-lengths for the glyserine are 0.25μ and 0.33μ respectively.

151. Glycerine.

See No. 150.

152. Potassium Permanganate.

Figures 84, 85 and 86, plates 22 and 23.

Grayish brown crystals with violet reflex.

In solution; deep violet; violet.

16.67 g. per liter.

Angle 27'.3. Depth 0 to 0.25 mm.

Five distinct bands clearly visible in the green with a very faint companion on the blue side. The central band of the five is a little more intense than its less refrangible neighbor. Light from the spark decomposes the potassium permanganate so rapidly with the formation of innumerable small bubbles that the exposures had to be made as follows. 1st. Expose to spark for 25 secs. 2nd. Remove cell from spectrograph and clean away the bubbles. 3rd. Replace the cell and make another exposure for 25 secs., and so on, three times for each distinct strip of the spectrogram. The absorption at 0.20μ is weak and decreases to transparency near 0.25μ. Unusual transparency from 0.25μ to 0.29μ. This fact is brought out in a half-dozen spectrograms of the region. A band of absorption extends roughly from 0.29 to 0.36μ with its maximum at the centre. The transparency increases to completeness and continues to 0.483μ. The wave-lengths of the seven photographic bands are 0.457 ,

0.472 μ, 0.488 μ, 0.505 μ, 0.525 μ, 0.545 μ and 0.570 μ. (Only five bands show on the complete spectrogram.) In decreasing order of intensity the three strongest bands are 0.525 μ, 0.505 μ and 0.545 μ.

An effort was made to detect the eight bands given by Formánek* but the conditions were not favorable to recording more than seven bands. Formanek's wave-lengths are "571.0, 547.3 (Hauptstreifen), 525.6, 505.4, 487.0, 470.7, 454.4, 439.5".

The negative for figure 86 plate 23 shows the seven bands. The solution was practically saturated since it contained 50 grams per liter at room temperature. Here the ultra-violet absorption extends as far as 0.39 μ. For concentrations from 16.67 to 50 grams per liter, and for the method used, the bands do not shift at all.**

Figure 85 plate 22 was obtained with trichromatic plates to see if any photographic bands less refrangible than 0.570 μ could be recorded. No evidence of the existence of such bands is presented. Concentration the same as for the complete spectrogram. Angle 31.2. Greatest depth of solution was 0.9 mm. Ultra-violet absorption extends to 0.39 μ. Intense absorption from 0.465 μ to 0.583 μ.

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* See J. Formanek, "Die qualitative Spectralanalyse anorganischer Korper," p. 59.

** See H. Kayser, "Handbuch der Spectroscopie", v. III p. 415.

153. Sodium Nitroprussid.

Figure 87, plate 23.

Garnet crystals.

In solution; reddish brown; light brown.

Saturated.

Angle 1° 45'. Depth 0 to 0.96 mm.

Weak absorption in violet. Light from the spark decomposes the solution at the very beginning of illumination so that the method used for photographing the ultra-violet absorption of the permanganates was not applicable. This difficulty was not overcome. Absorption decreases to about 0.38 μ then increases to a weak maximum near 0.396 μ and finally decreases to transparency at 0.428 μ. No selective absorption from 0.43 μ to 0.62 μ.

It gives the writer much pleasure to have the opportunity of publicly acknowledging here his lasting indebtedness to Professor J. S. Ames both for the interest which he took at all times in the present work and for freely placing at the disposal of the writer the apparatus, materials and experimental facilities of the Physical laboratory.

The same sense of obligation is due Professor R. W. Wood for suggesting the subject of this research and for his ready

counsel and assistance throughout.

In conclusion the writer desires to thank all individuals who were instrumental in procuring the chemicals for the work and especially Professor H. Kayser, who used his influence in furtherance of this end, the Actiengesellschaft für Anilinfabrikation, and the firm of Meister, Lucius & Brüning. Each of these firms presented the Physical Department of the Johns Hopkins University with a large collection of coloring matters of their own manufacture.

For convenience in identifying the stronger spark lines figure 91 plate 24 is given.* The numbers on this positive correspond to those preceding the wave-lengths below. The wave-lengths were derived from the two following sources.

"An introduction to the Study of Spectrum Analysis" by W. M. Watts. Longmans, Green & Co., 1904.

"Measurements of the Wave-lengths of Lines of High Refrangibility in the Spectra of Elementary Substances." Hartley and Adeney. From the Philosophical Transactions of the Royal Society. Part I, 1884.

1	2024.2	Zn.	15	2558.0	Zn.
2	2060.8	Zn.	16	2573.1	Cd.
	2062.8	Zn.			
			17	2710.1	Air.
3	2099.0	Zn.		2712.6	Zn .
4	2138.3	Zn.	18	2748.7	Cd.
5	2144.5	Cd.	19	2770.9	Zn.
6	2194.7	Cd.	20.	2801.0	Zn.
7	2239.9	Cd.	21	2837.0	Cd.
8	2265.1	Cd.	22	2880.9	Cd.
9	2288.1	Cd.	23	2980.8	Cd.
10	2306.7	Cd.	24	3007.0	Air.
11	2313.0	Cd.	25	3035.9	Zn.
12	2321.2	Cd.	26	3072.2	Zn.
				3076.0	Zn.
13	2329.3	Cd.			
			27	3133.3	Cd
14	2502.1	Zn	28	3250.5	Cd.

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* The negative was not a single exposure. To stand reproduction the extreme ultra-violet was "favored."

29	3261.2	Cd.
30	3282.4	Zn.
31	3302.7	Zn.
32	3329.3	Air
	3331.5	Air.
33	3345.1	Zn.
	3345.5	Zn.
34	3403.7	Cd.
35	3436.9	Air
36	3466.3	Cd.
	3467.8	Cd.
37	3535.0	Cd.
38	3610.7	Cd.
	3613.0	Cd.
39	3682.6	"Doubtful origin".
40	3712.2	Air.
41	3726.6	Air.
42	3749.8	Air.
43	3839.3	Air.
	3841.7	Air.
44	3881.9	Air.
45	3919.2	Air.
46	3954.8	Air.
	3956.2	Air.
47	3972.5	Air.
48	3995.1	Air.
49	4041.4	Air.
50	4070.0	Air.
	4072.4	Air.
	4076.1	Air.
51	4119.4	Air.
52	4132.8	Air.
	4133.8	Air
53	4145.9	Air.
54	4151.9	Air.
	4153.6	Air.
55	4228.5	Air.
	4236.7	Air.
	4241.9	Air.
56	4316.2	Air.
	4318.7	Air.
57	4349.5	Air
58	4367.9	Air.
59	4415.1	Air.
60	4447.1	Air.
	4447.2	Air.
61	4530.1	Air.
62	4576.2	Cd. 9_2.
63	4601.6	Air.
64	4607.3	Air.
65	4614.0	Air.
66	4621.6	Air.
67	4626.0	Cd. 11_2.
68	4630.7	Air.
69	4641.9	Air.
	4643.4	Air.

70	4649.2	Air.	
71	4680.4	Zn.	
72	4722.3	Zn.	
73	4800.1	Cd.	
74	4810.7	Zn.	
75	4912.3	Zn.	
76	4924.8	Zn.	
77	5002.7 5005.7	Air. Air.	
78	5045.7	Air.	
79	5086.1	Cd.	
80	5116.0	Zn	15_2.
81	5146.2	Cd.	16_2.
82	5338.6	Cd.	
83	5354.4	Cd.	—.
84	5379.3	Cd.	
85	5497.4	Cd.	18_2.
86	5509.0	Zn.	—$_2$.
87	5541.8	Zn.	19_2.
88	5602.0	Zn.	20_2.
89	5761.8	Cd.	22_2.
90	5961.6	Cd.	23_2.
91	6014.0	Air.	24_2.
92	6035.0	Zn.	—$_2$.
93	6071.8	Zn.	25_2.
94	6144.4	Zn.	26_2.
95	6152.0	Zn.	26_2.
96	6160.4	Cd.	—$_2$.
97	6266.6	Cd.	27_2.

ALPHABETICAL INDEX OF ABSORBING MEDIA.

Name.	Page	No.	Plate	Fig.
Acid Brown.	78	42		
Acid Green, conc.	104	86	11	44
Acid Magenta S.	136	133		
Acid Rosamine A.	118	106	15	58
Aesculine.	143	146	21	80&81
Alizarine Blue S.	128	120	18	70
Alizarine Brown.	126	118		
Alizarine Green B.	132	128		
Alizarine Orange. (Powder 80%.)	136	134	20	76
Alizarine Red No. 1, 40%.	137	135		
Alizarine Red S.	127	119	18	69
Alkali Blue 6 B.	112	97	14	53
Amidonaphtholdisulphonic Acid H.	55	1	1	1
Anthracene Yellow C.	85	53		
Anthracene Red.	90	62		
Auramine O.	102	82	11	43
Aurantia.	58	8	2	7
Aurophosphine 4 G.	138	136	20	77
Azo Acid Yellow.	71	31		
Azo Blue.	96	72		
Azo Coccine 2 R.	61	14	3	13

Name.	Page	No.	Plate	Fig.
Azo Rubine S.	74	35		
Azo Yellow, conc.	71	31		
Barium Permanganate.	144	147		
Benzoazurine.	98	75		
Benzopurpurine B.	92	65		
Benzopurpurine 6 B.	91	64		
Benzopurpurine 10 B.	97	74	10	39
Biebrich Scarlet.	82	49		
Bismarck Brown.	85	54	3	11
Blue Black.	84	52		
Bordeaux B.	64	19	4	16
Brilliant Congo R.	93	67	10	37
Brilliant Croceine, blue shade.	138	137		
Brilliant Orange G.	62	15	4	14
Brilliant Purpurine 10 B.	139	138		
Brilliant Purpurine R.	94	69	10	37
Carborumdum.	144	148	21	82
China Blue.	113	99	14	54
Chromotrope 6 B.	61	13	3	12
Chrysamine G.	87	57		
Chrysoïdine.	60a.	12	3	11
Cloth Red G.	80	45	7	27
Cloth Red 3 G A.	81	47	8	29

Name	Page	No.	Plate	Fig.
Cloth Red O.	80	46	7	28
Coccinine B.	65	20		
Columbia Fast Scarlet 4 B.	139	139	10	37
Columbia Yellow.	133	129	19	74
Congo Brown G.	99	77	10	40
Congo Brown R.	100	78	10	40
Congo Corinth.	95	71		
Congo Corinth G.	89	60		
Congo Orange G.	86	56	9	33
Congo Orange R.	91	63		
Congo Red.	88	59	9	35
Congo Rubine.	89	61	9	36
Coralline Red.	114	100	14	55
Cresotine Yellow G.	88	58	9	34
Crystal Ponceau 6 R.	64	18		
Crystal Violet .	107	90		
Curcumeine.	71	30	5	21
Curcumine S.	101	81	11	42
Cyanosine.	123	113	17	65
Dahlia.	107	89	12	46
Deltapurpurine 5 B.	93	66		
Diamine Black B O.	97	73		
Diamine Green B.	99	76		

Name.	Page	No.	Plate	Fig.
Diamine Red B.	93	66		
Diamine Red 3 B.	94	68	10	38
Diamond.	147	149	21	82
Dianil Orange G.	140	140	20	78
Dianil Yellow R.	76	40		
Emerald Green.	103	84		
Emin Red.	67	23	5	19
Eosamine B.	66	21	4	17
Eosine a l'alcool.	121	109	16	62
Eosine, bluish.	122	111	17	63
Eosine, yellowish	120	108		
Erika B.	66	22	5	18
Erythrosine.	123	112	17	64
Ethyl Alcohol.	147	150	22	83
Ethyl Violet.	108	91	12	47&48
Fast Acid Violet A 2 R.	117	105		
Fast Acid Violet B.	116	104		
Fast Brown 3 B.	75	38	7	25
Fast Green O.	100	79		
Fast Red A.	73	34	6	24
Fast Red, extra.	74	36		
Fast Yellow.	59	9	2	8
Fluoresceïne.	140	141		
Fuchsine.	105	87		
Fuchsine S.	111	95	13	51

Name	Page	No.	Plate	Fig.
Galleïne.	125	116		
Glycerine.	147	151	22	83
Guinea Carmine B.	141	142	21	79
Heliotrope 2 B.	130	124	19	72
Indigo Carmine, dry.	135	132		
Janus Green.	67	24		
Janus Red B.	79	44		
Light Green F.S.	104	85		
Malachite Green.	103	83		
Metanil Yellow.	72	32	6	22
Methyl Blue .	113	98		
Methyl Eosine.	122	110		
Methyl Green.	110	94	13	50
Methyl Green 00.	109	93		
Methyl Orange III.	69	28	5	20
Methyl Violet 6 B.	109	92	13	49
Mordant Yellow O.	76	39		
Naphthalene Red.	132	127	19	73
β-Naphtholdisulphonic Ạ̃cid G.	55	2	1	2 & 3
Naphthol Green B.	101	80	11	41
Naphthol Yellow.	58	7	2	6
Naphthol Yellow S.	58	7	2	6

Name.	Page	No.	Plate	Fig.
Naphthylamine Brown.	72	33	6	23
Neutral Red.	128	121		
New Coccine.	75	37		
New Coccine O.	73	34	6	24
New Magenta.	106	88	12	45
Night Blue.	114	101		
Nigrosine, soluble.	131	126		
p-Nitraniline.(Powder,"extra".)	56	3		
O-Nitrobenzaldehyde.	56	4		
p-Nitrosodimethylaniline.	56	5	1	5
Orange G.	59	10	2	9
Phenosafranine.	129	122	19	71
Phloxine.	124	115	18	67
Phosphine.	126	117	18	68
Ponceau B O., extra.	78	43		
Ponceau 2 G.	60	11	3	10
Ponceau 2 R.	63	16		
Ponceau 3 R.	63	17	4	15
Ponceau 4 R B.	81	48	8	30
Ponceau 6 R B.	83	51	8	32
Potassium Permanganate.	148	152	22& 23	84,85 &86

Name.	Page	No.	Plate	Fig.
Quinoline Blue.	134	130		
Quinoline Yellow O.	134	131	20	75
Quinoline Yellow, sol. in water.	134	131	20	75
Red Violet 5 R S.	111	96	13	52
Resorcine (techn. pure.)	57	6	1	4
Resorcine Brown.	77	41	7	26
Rhodamine B.	115	103	15	57 a 57 b
Rosazurine B.	95	70		
Rose Bengal.	124	114	17	66
Rosolane O.	131	125		
Safranine.	129	123		
Sodium Nitroprussid.	150	153	23	87
Soluble Prussian Blue.	141	143		
Thiogene Brown S.	142	144		
Thiogene Orange R.	142	145		
Tropaeoline O.	68	25		
Tropaeoline OO.	70	29		
Tropaeoline OOO No. 1.	68	26		
Tropaeoline OOO No. 2.	69	27		
Uranine.	118	107	15&16	59,60 &61
Vesuvine.	86	55	3	11
Victoria Blue 4 R.	115	102	14	56
Wool Black.	83	50	8	31

PART III.

PLATES.

PLATE I.

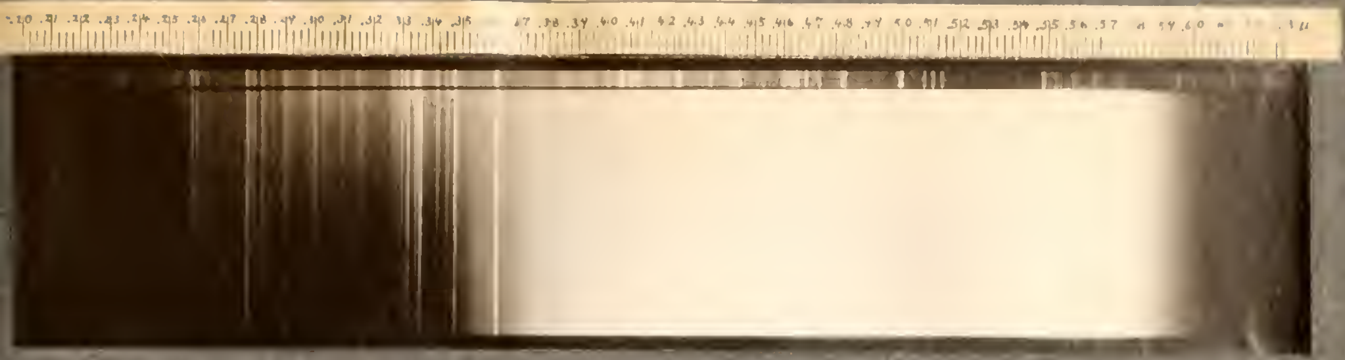

Fig. 1. See No. 1 page 55.

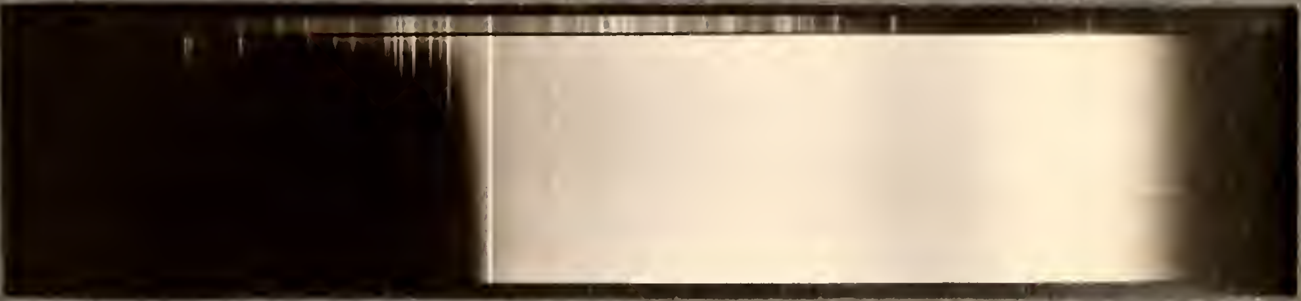

Fig. 2. See No. 2 page 55.

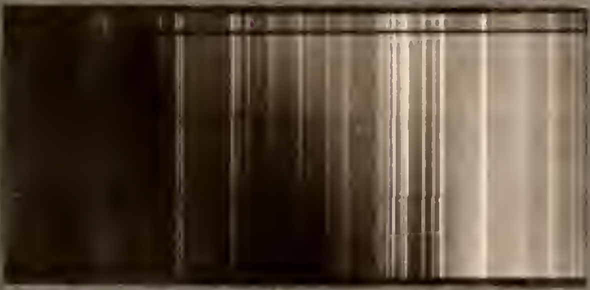

Fig. 3. See No. 2 page 55.

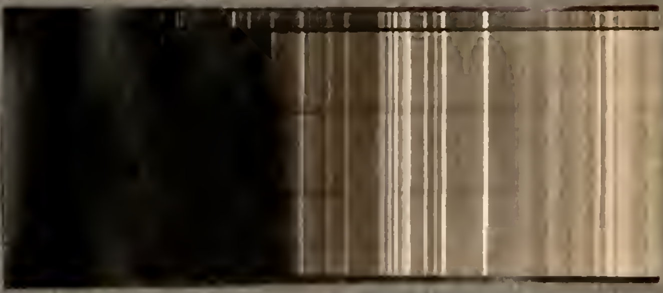

Fig. 4. See No. 6 page 57.

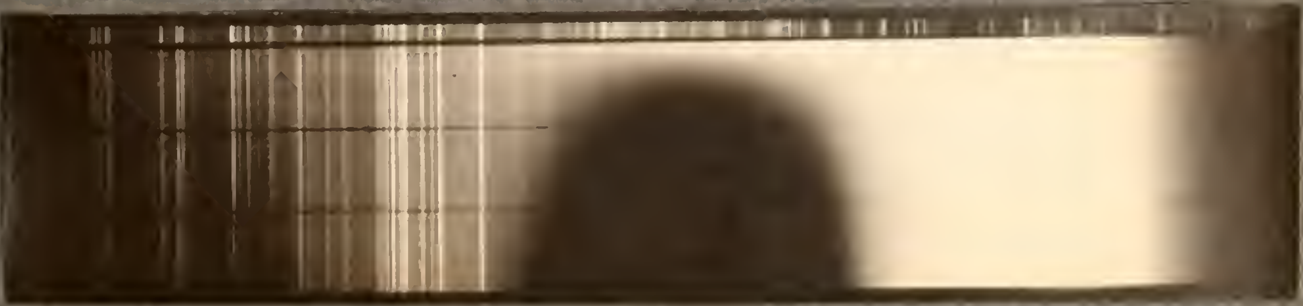

Fig. 5. See No. 5 page 56.

PLATE II.

Fig. 6. See No. 7 page 58.

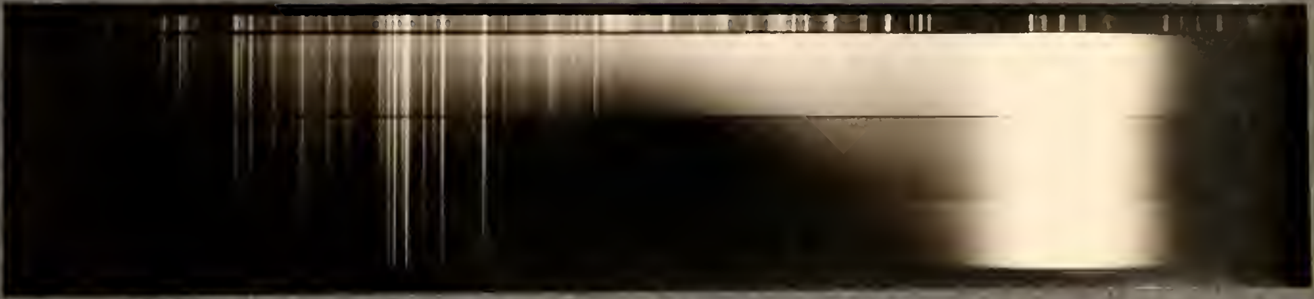

Fig. 7. See No. 8 page 58.

Fig. 8. See No. 9 page 59.

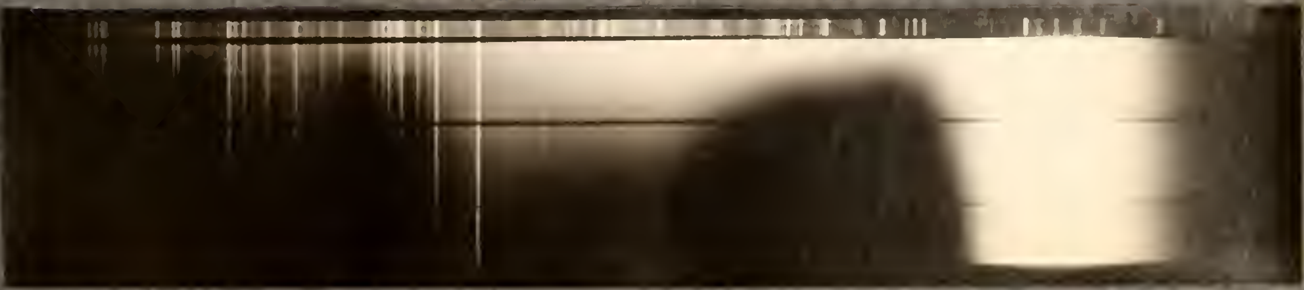

Fig. 9. See No. 10 page 59.

PLATE III.

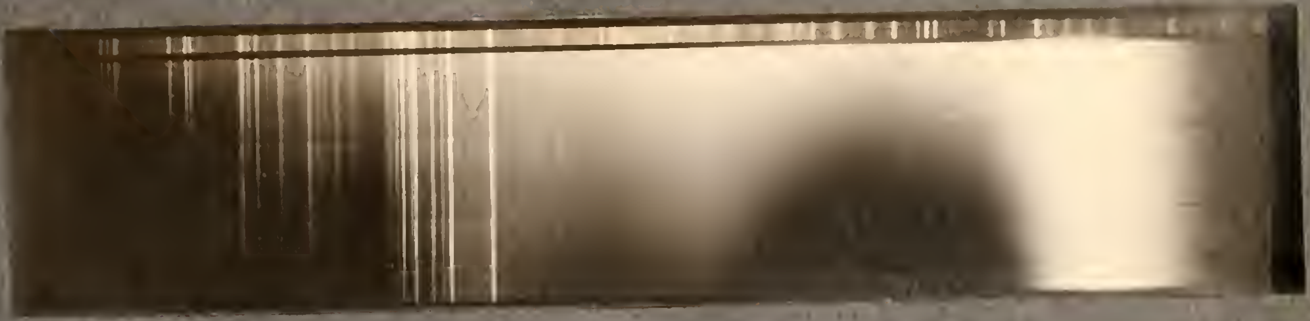

Fig. 10. See No. 11 page 60.

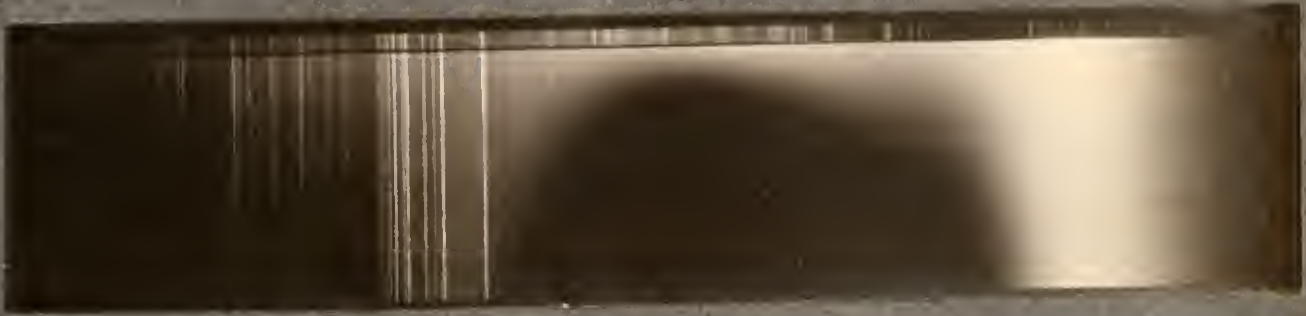

Fig. 11. See No. 12 page 60 a.

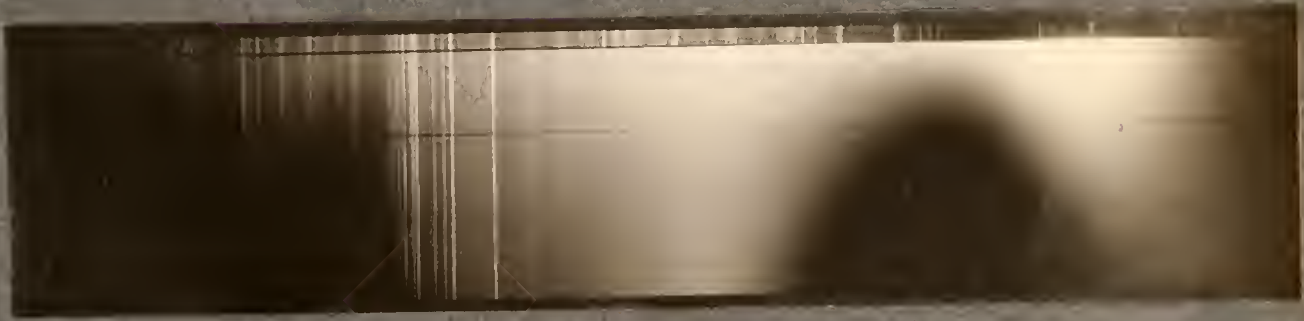

Fig. 12. See No. 13 page 61.

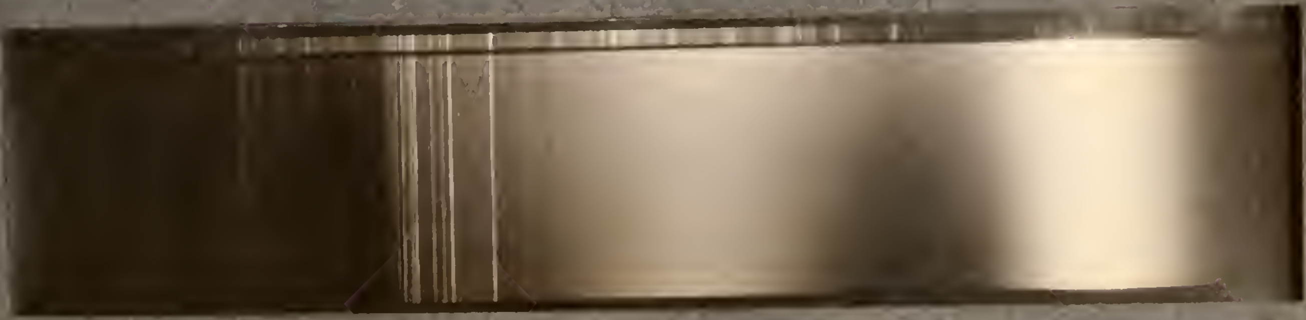

Fig. 13. See No. 14 page 61.

PLATE IV.

Fig. 14. See No. 15 page 62.

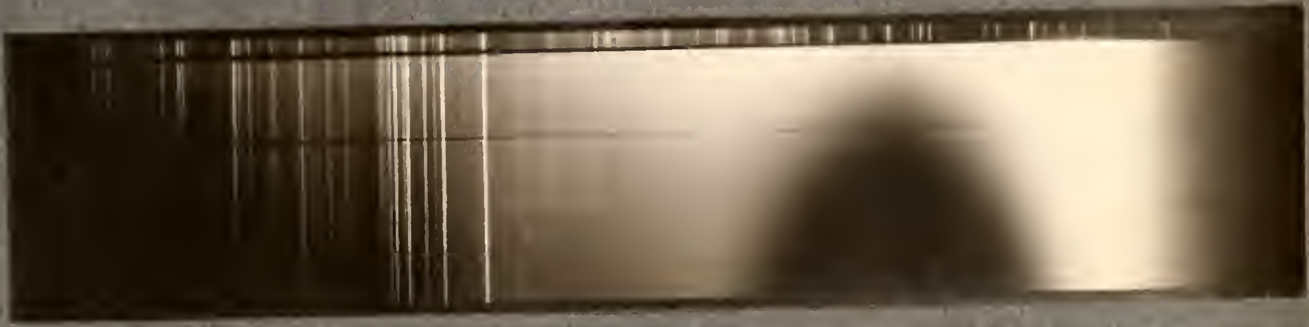

Fig. 15. See No. 17 page 63.

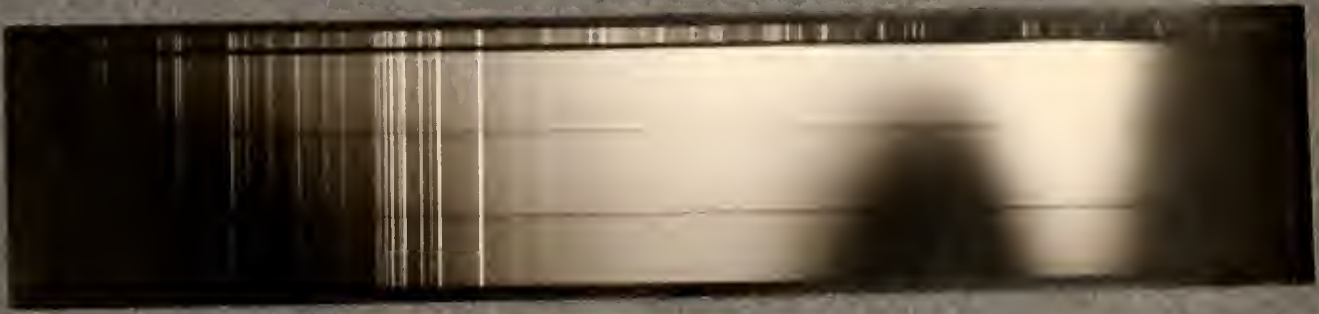

Fig. 16. See No. 19 page 64.

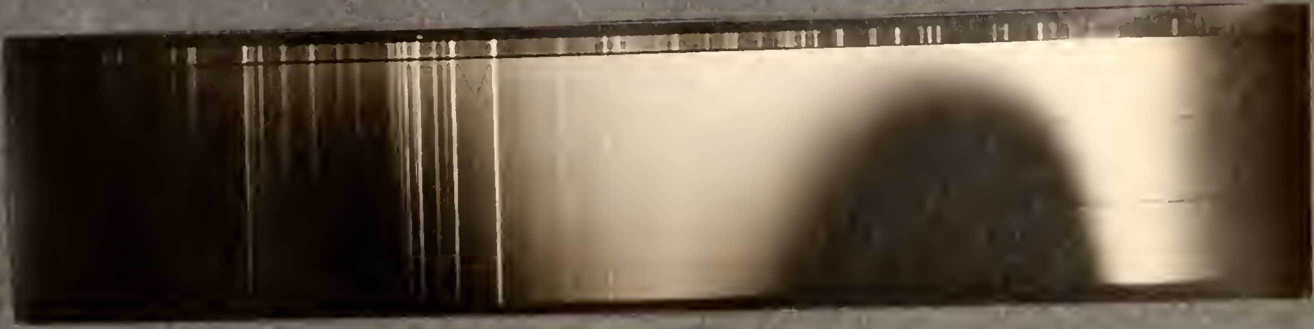

Fig. 17. See No. 21, page 66.

PLATE V.

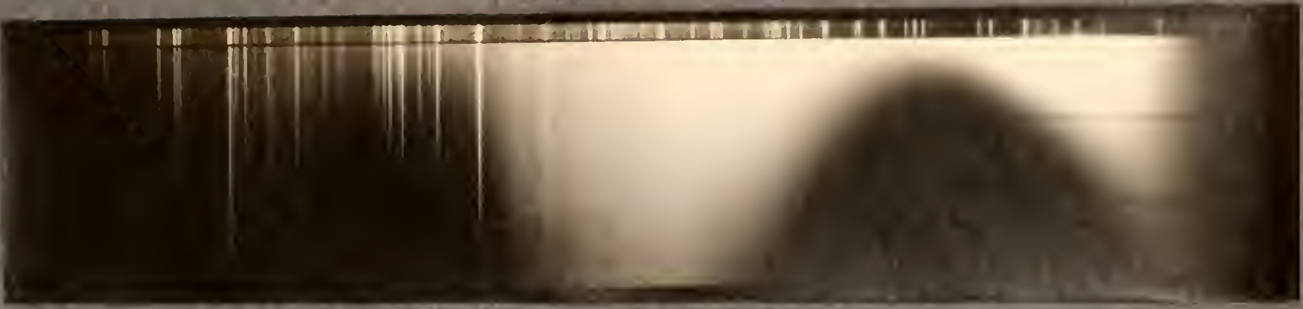

Fig. 18. See No. 22 page 66.

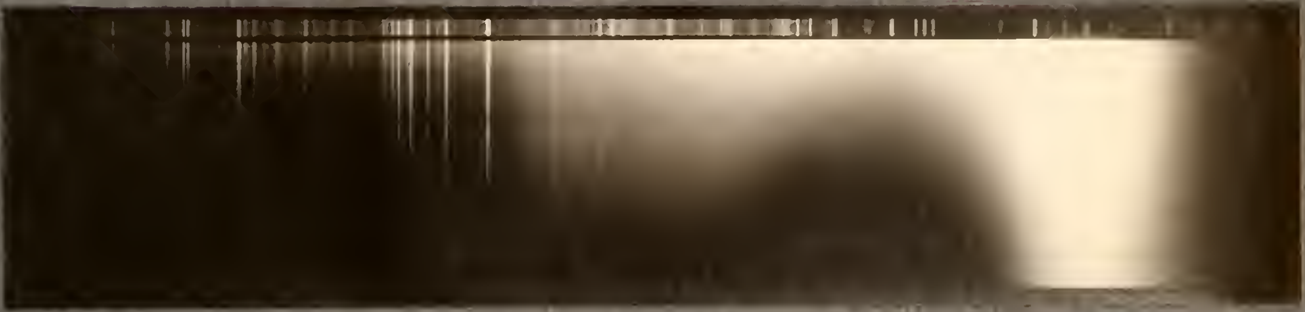

Fig. 19. See No. 23 page 67.

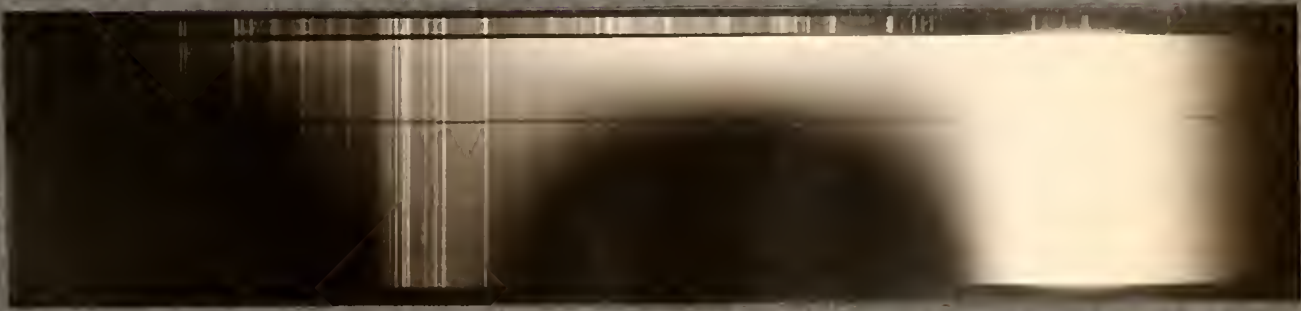

Fig. 20. See No. 28 page 69.

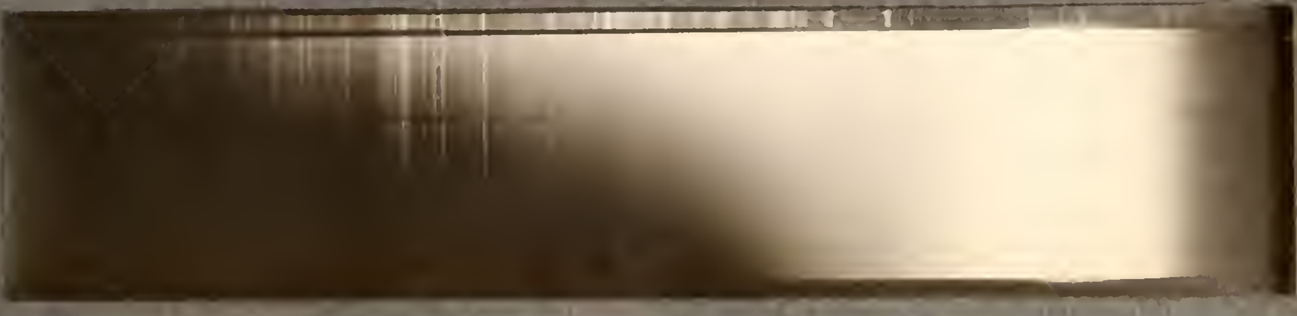

Fig. 21. See No. 30 page 71.

PLATE VI.

Fig. 22. See No. 32 page 72.

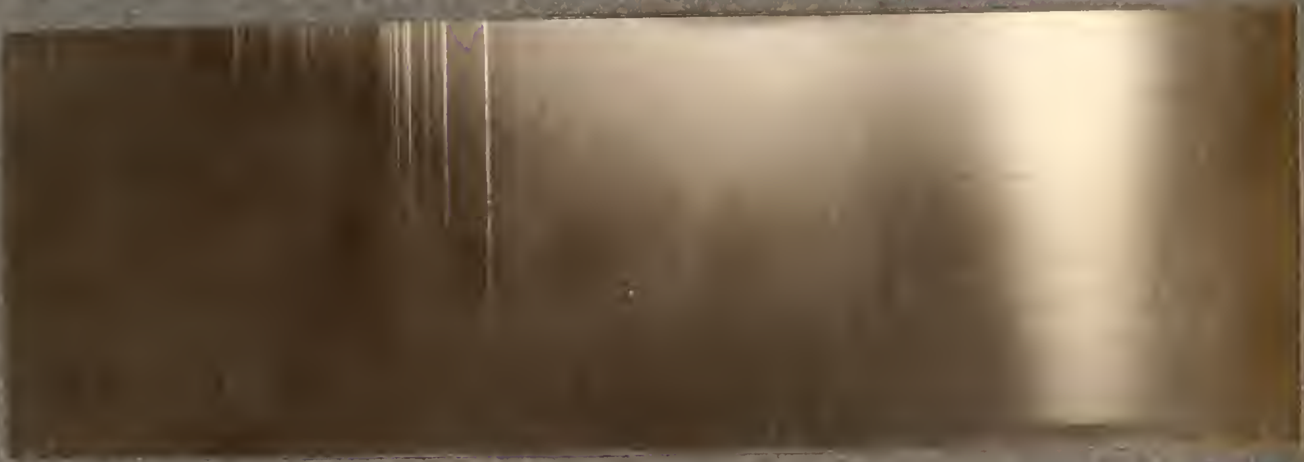

Fig. 23. See No. 33 page 72.

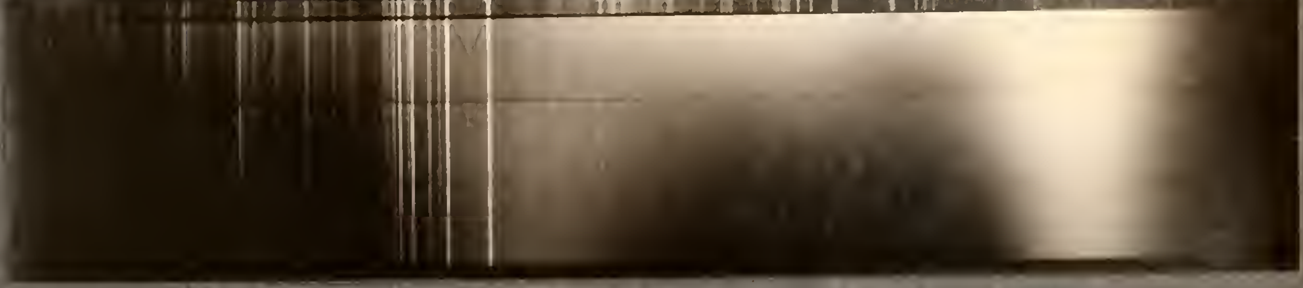

Fig. 24. See No. 34 page 73.

PLATE VII.

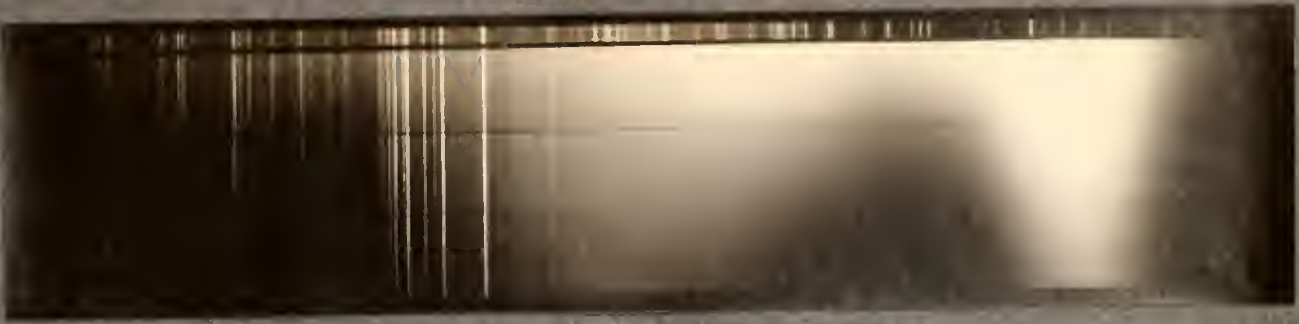

Fig. 25. See No. 38 page 75.

Fig. 26. See No. 41 page 77.

Fig. 27. See No. 45 page 80.

Fig. 28. See No. 46 page 80.

PLATE VIII.

Fig. 29. See No. 47 page 81.

Fig. 30. See No. 48 page 81.

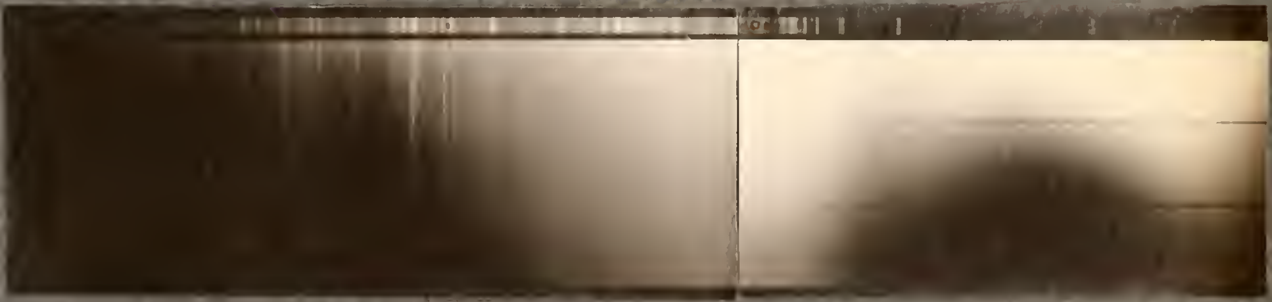

Fig. 31. See No. 50 page 83.

Fig. 32. See No. 51 page 83.

PLATE IX.

Fig. 33. See No. 56 page 86.

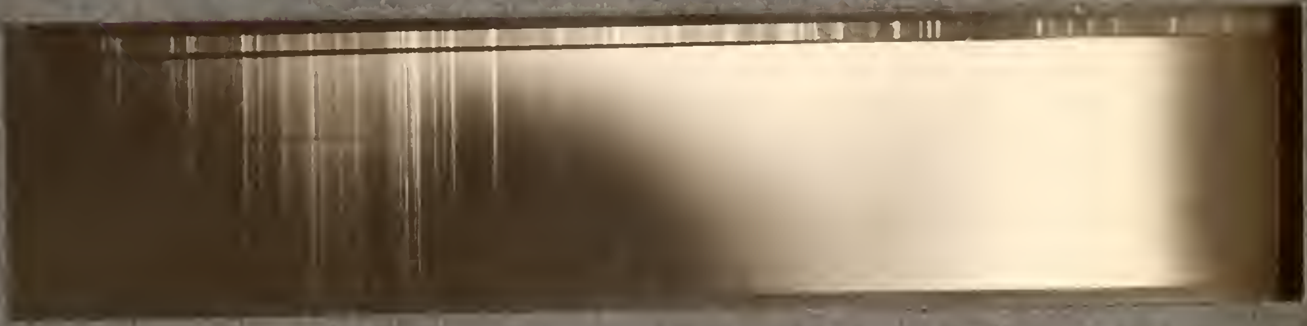

Fig. 34. See No. 58 page 88.

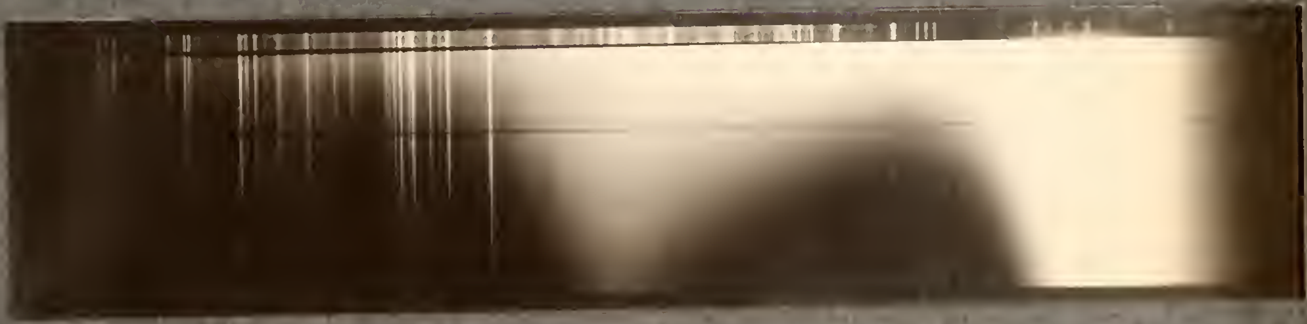

Fig. 35. See No. 59 page 88.

Fig. 36. See No. 61 page 89.

PLATE X.

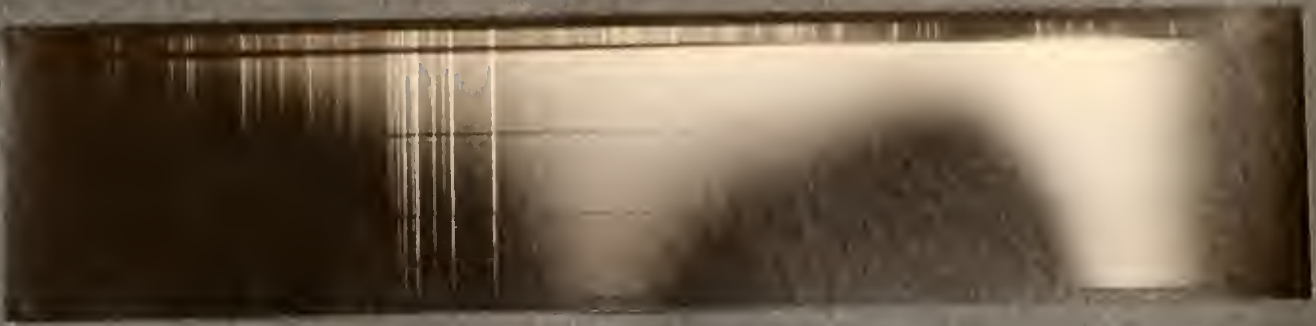

Fig. 37. See No. 67 page 93.

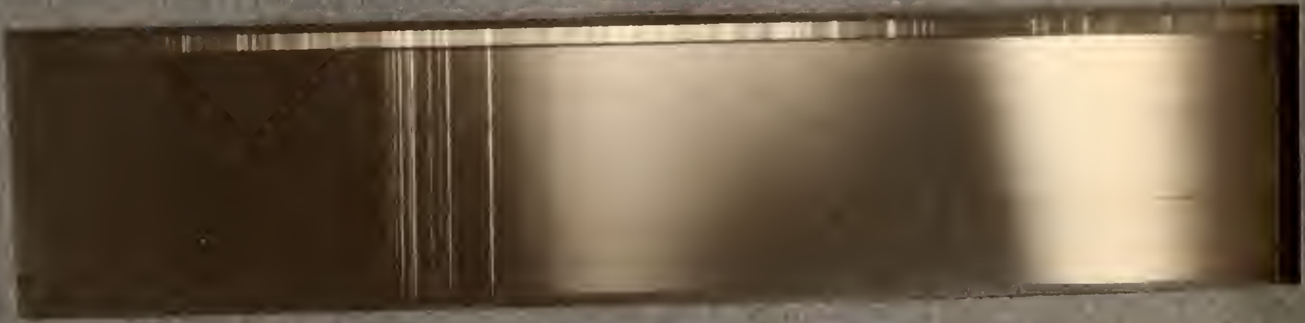

Fig. 38. See No. 68 page 94.

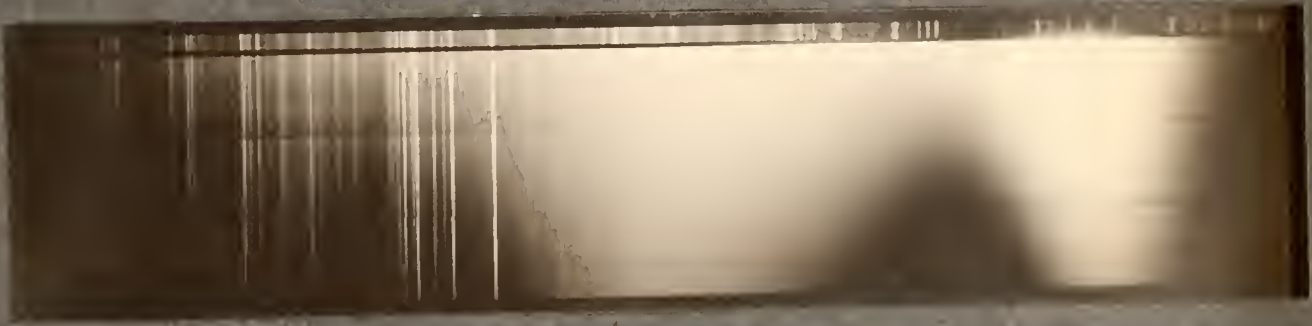

Fig. 39. See No. 74 page 97.

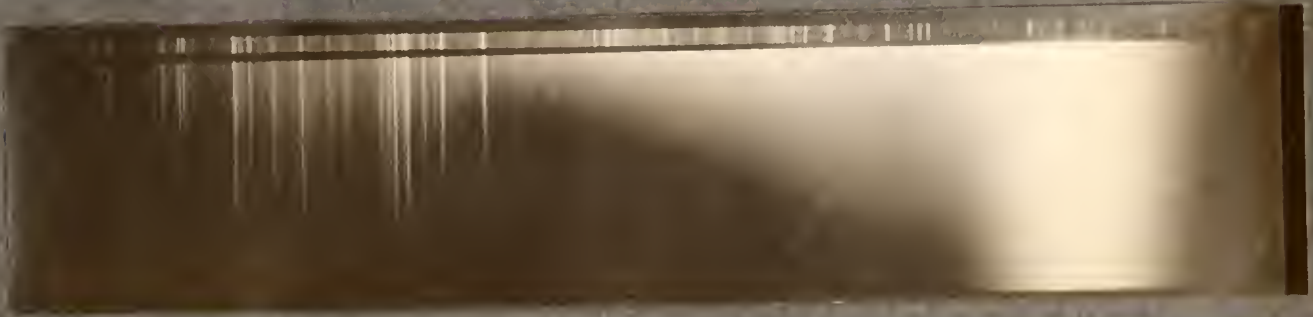

Fig. 40. See No. 77 page 99.

PLATE XI.

Fig. 41. See No. 80 page 101.

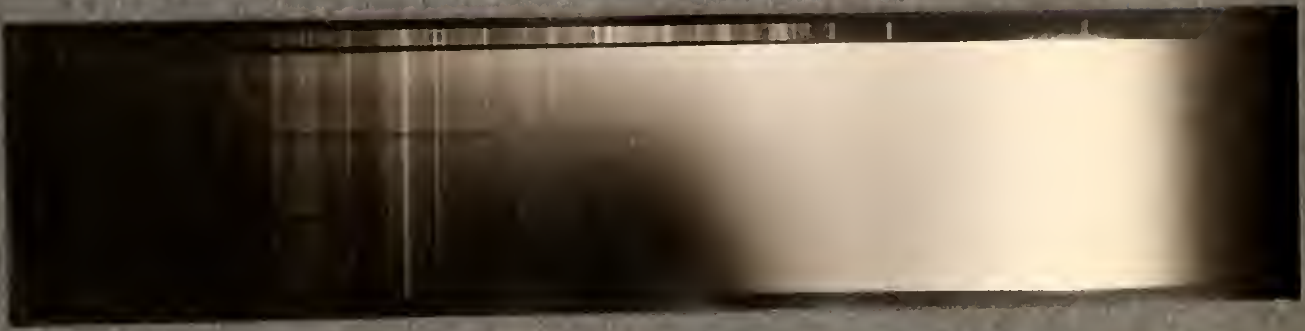

Fig. 42. See No. 81 page 101.

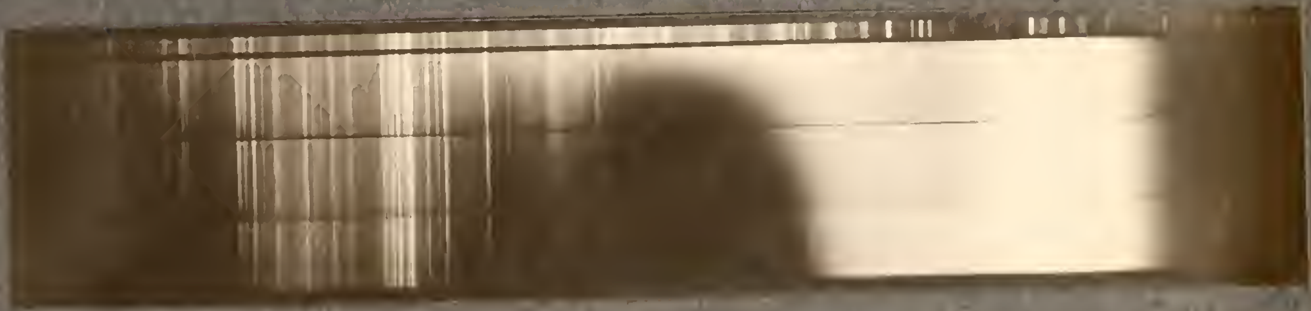

Fig. 43. See No. 82 page 102.

Fig. 44. See No. 86 page 104.

PLATE XII.

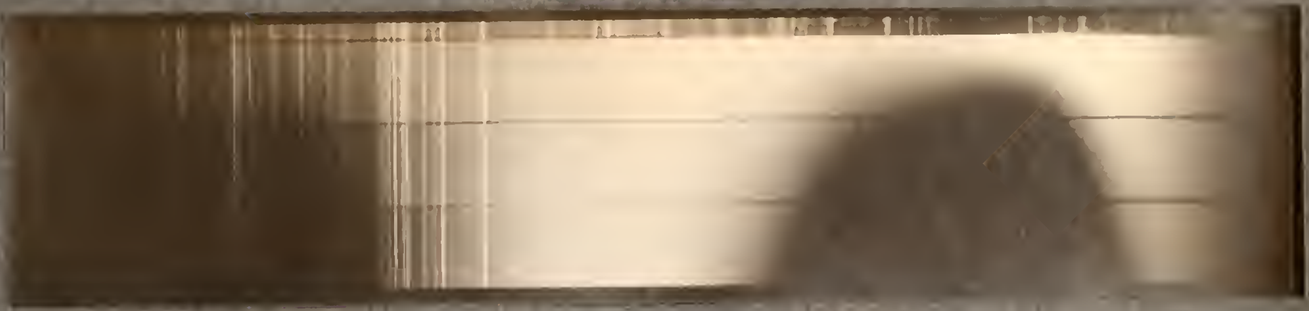

Fig. 45. See No. 88 page 106.

Fig. 46. See No. 89 page 107.

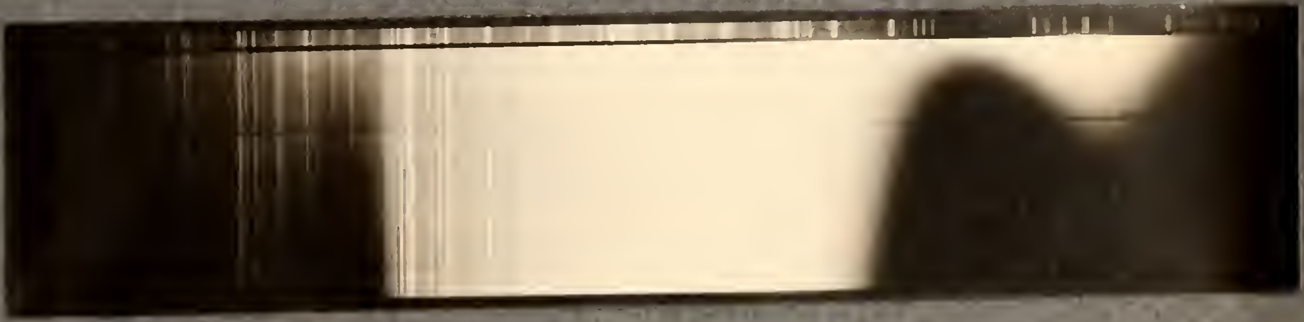

Fig. 47. See No. 91 page 108.

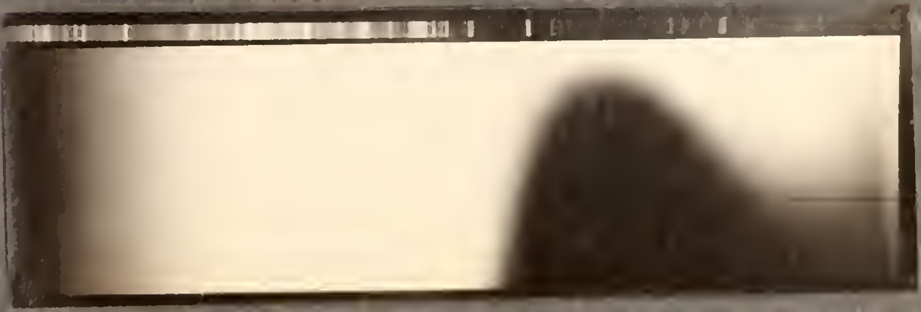

Fig. 48. See No. 91 page 108.

PLATE XIII.

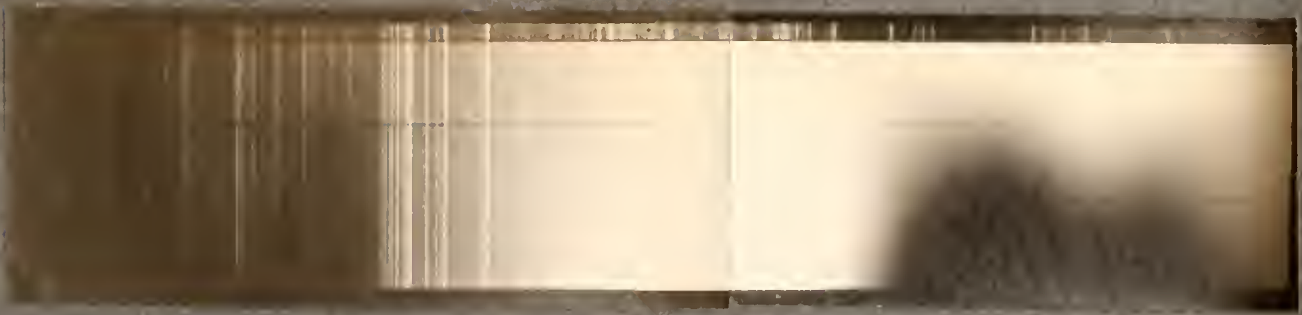

Fig. 49. See No. 92 page 109.

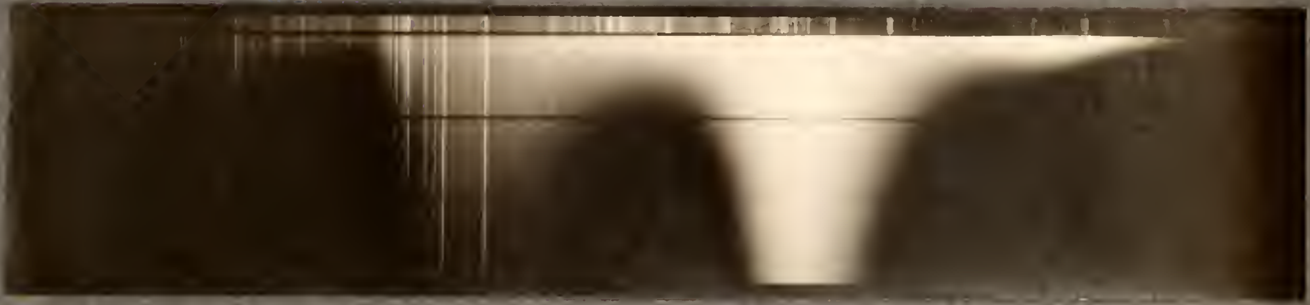

Fig. 50. See No. 94 page 110.

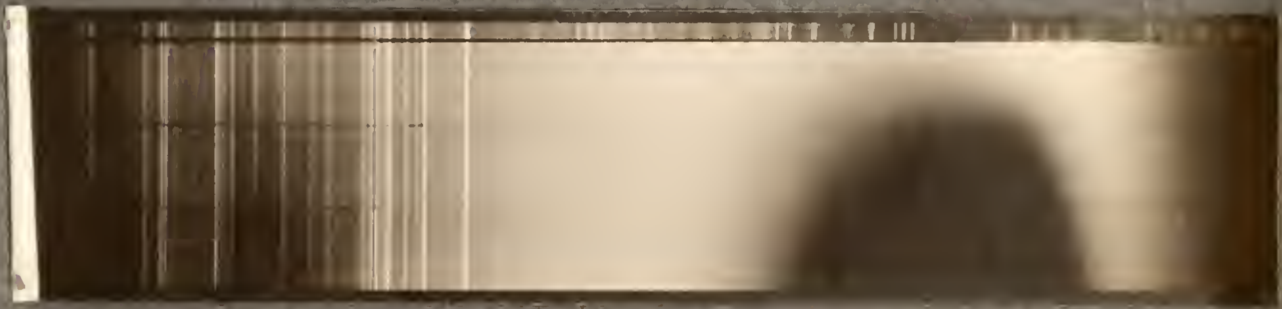

Fig. 51. See No. 95 page 111.

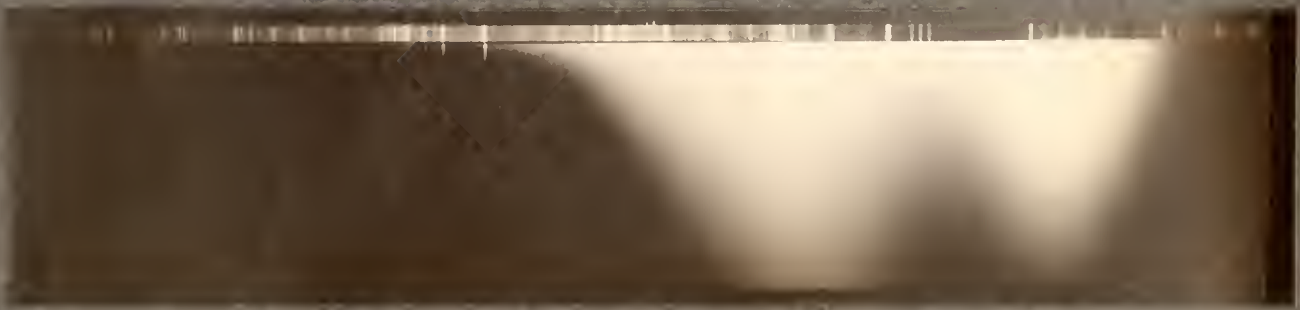

Fig. 52. See No. 96 page 111.

PLATE XIV.

Fig. 53. See No. 97 page 112.

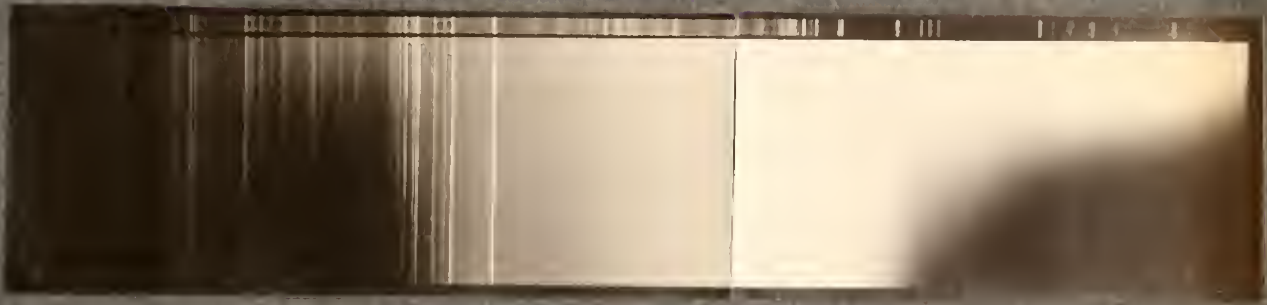

Fig. 54. See No. 99 page 113.

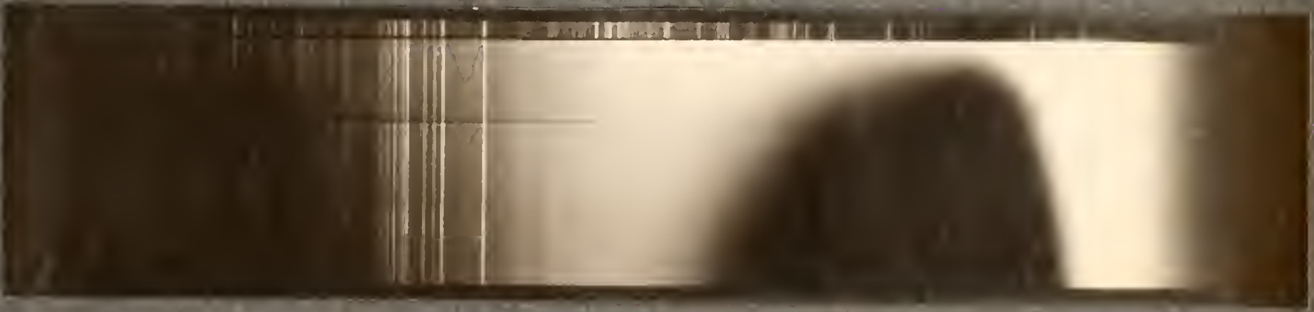

Fig. 55. See No. 100 page 114.

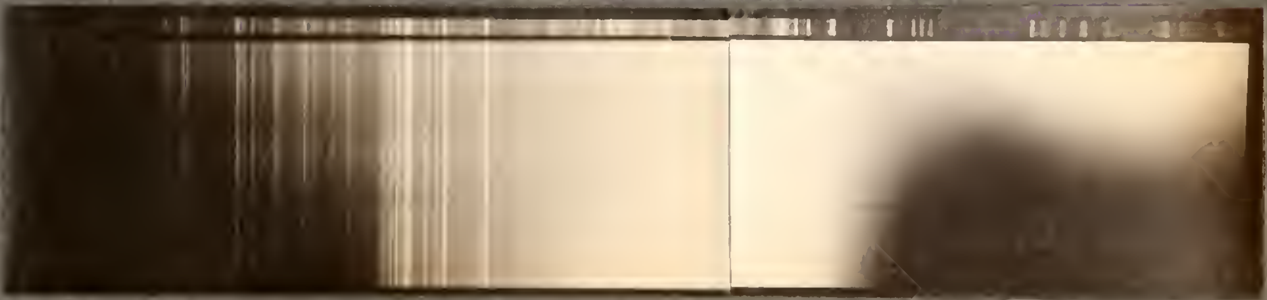

Fig. 56. See No. 102 page 115.

PLATE XV.

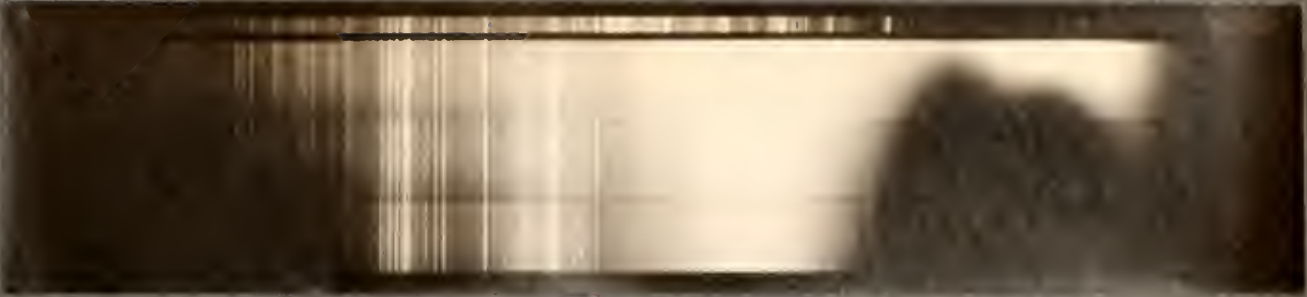

Fig. 57 a. See No. 103 page 115.

Fig. 57 b. See No. 103 page 115.

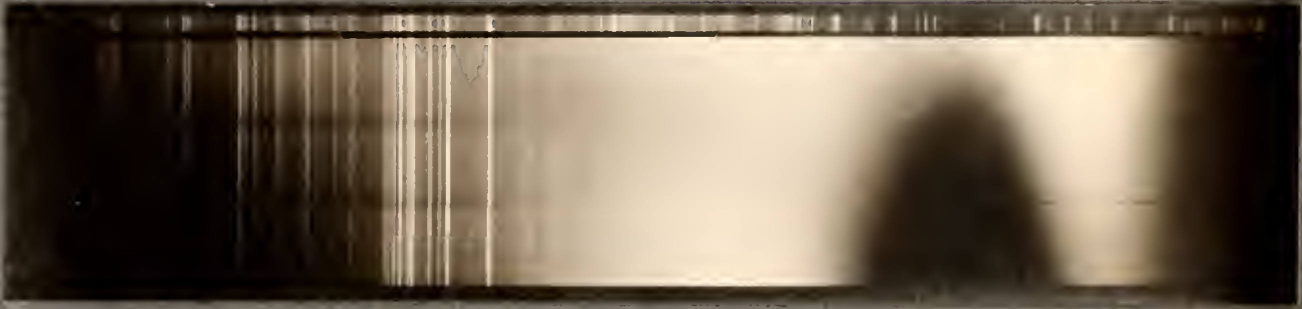

Fig. 58. See No. 106 page 118.

Fig. 59. See No. 107 page 118.

PLATE XVI.

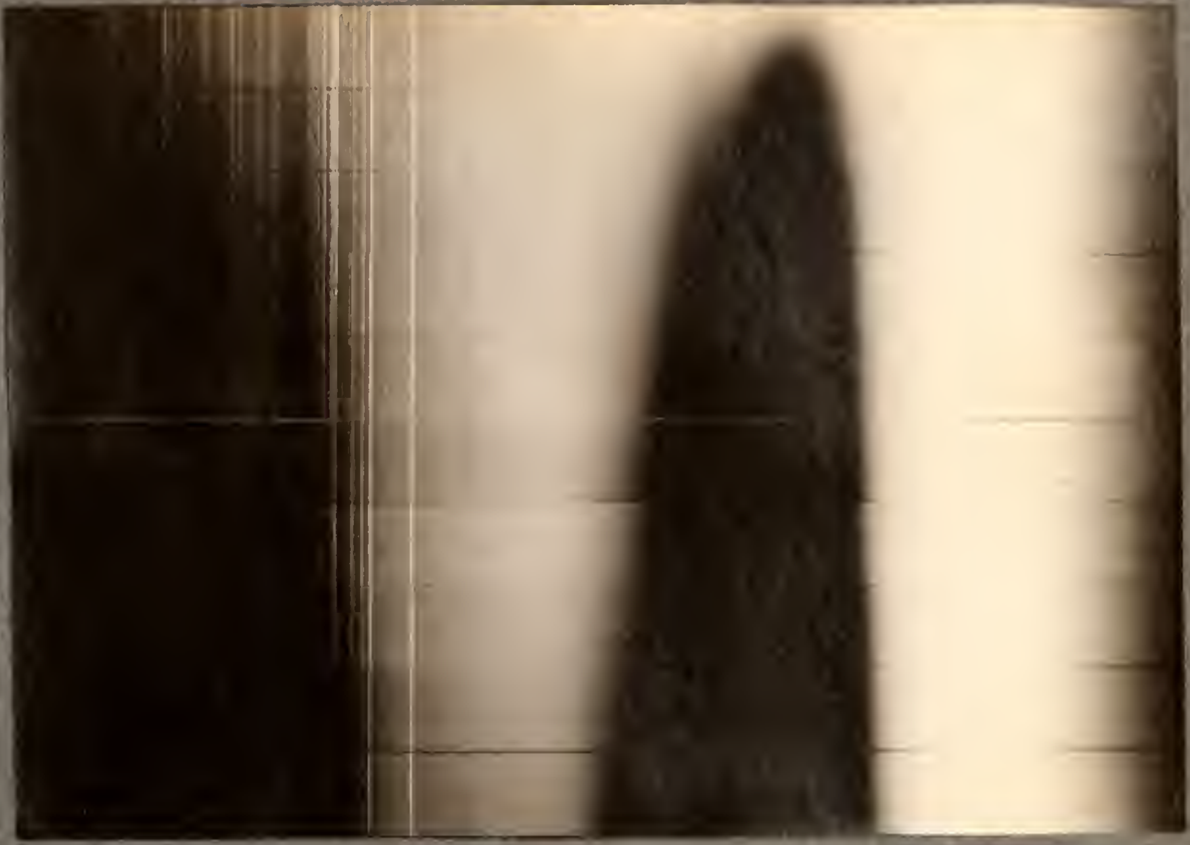

Fig. 60. See No. 107 page 118.

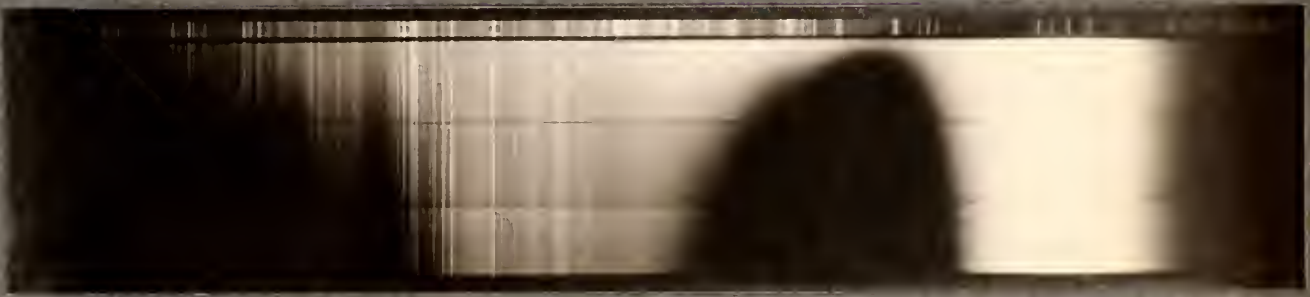

Fig. 61. See No. 107 page 118.

Fig. 62. See No. 109 page 121.

PLATE XVII.

Fig. 63. See No. 111 page 122.

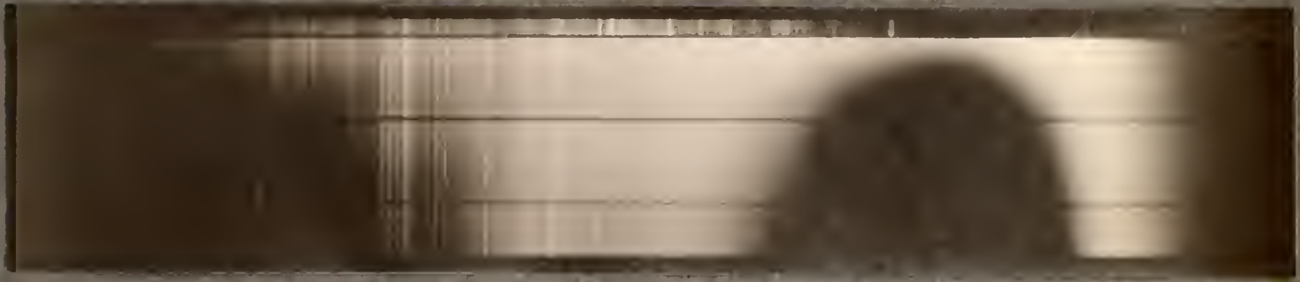

Fig. 64. See No. 112 page 123.

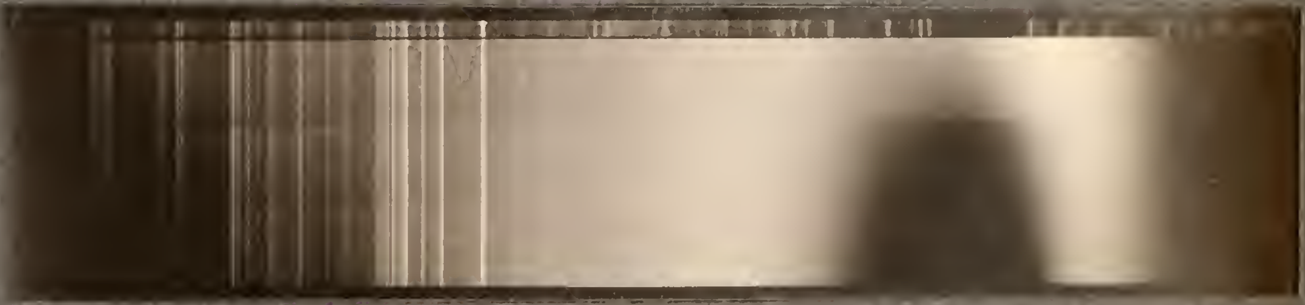

Fig. 65. See No. 113 page 123.

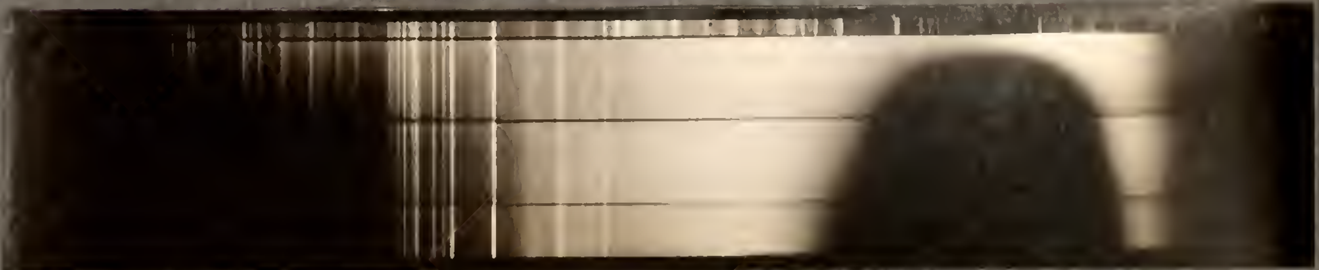

Fig. 66. See No. 114 page 124.

PLATE XVIII.

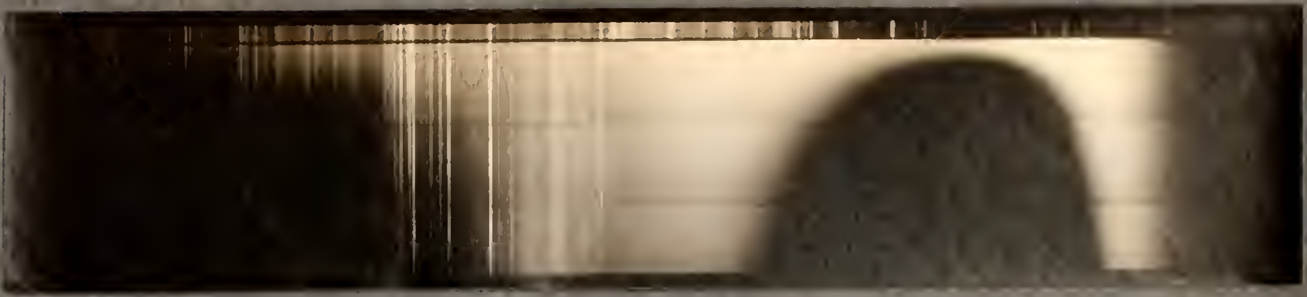

Fig. 67. See No. 115 page 124.

Fig. 68. See No. 117 page 126.

Fig. 69. See No. 119 page 127.

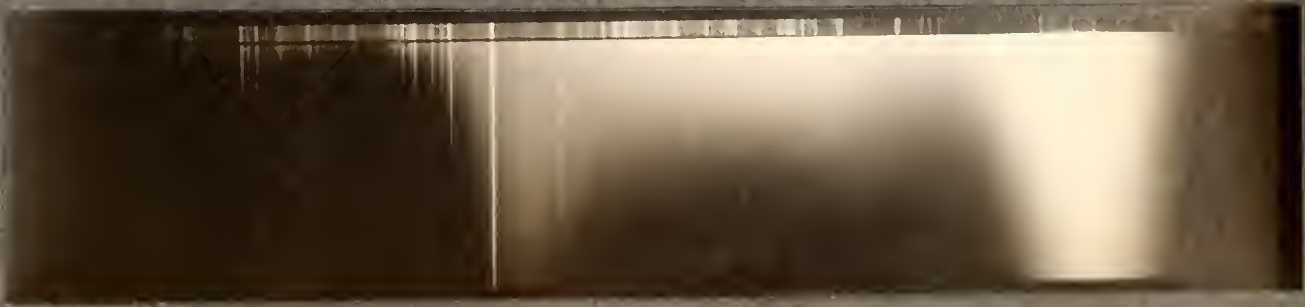

Fig. 70. See No. 120 page 128.

PLATE XIX.

Fig. 71. See No. 122 page 129.

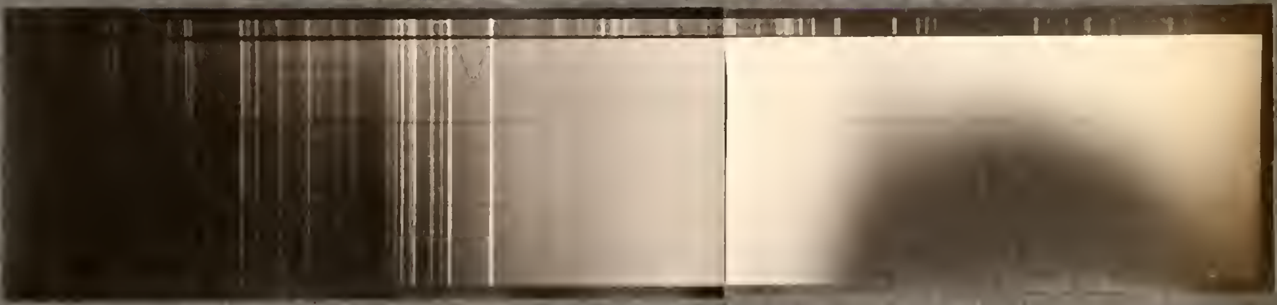

Fig. 72. See No. 124 page 130.

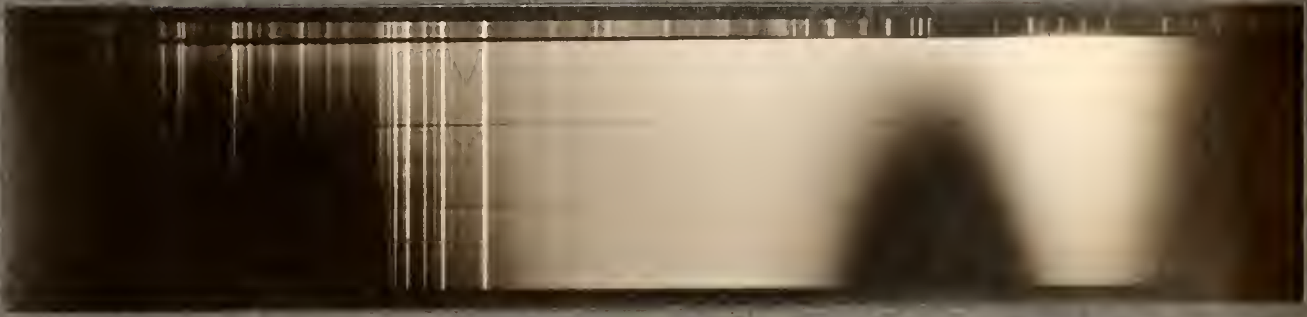

Fig. 73. See No. 127 page 132.

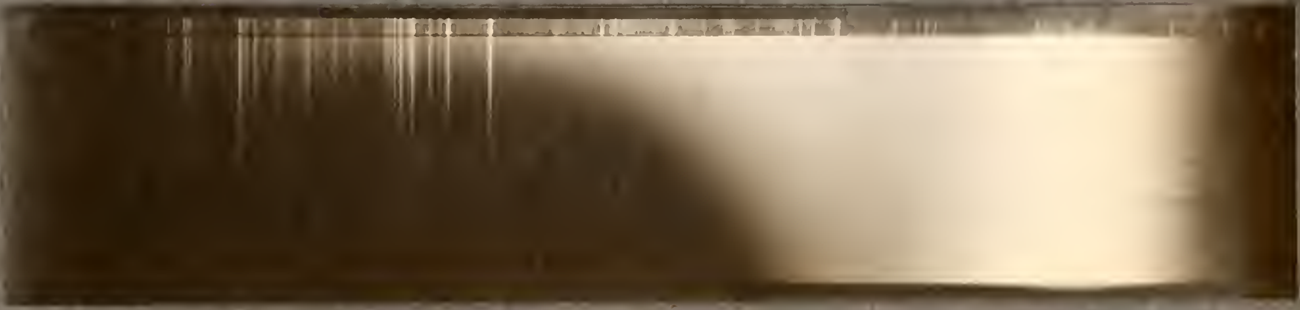

Fig. 74. See No. 129 page 133.

PLATE XX.

Fig. 75. See No. 131 page 134.

Fig. 76. See No. 134 page 136.

Fig. 77. See No. 136 page 138.

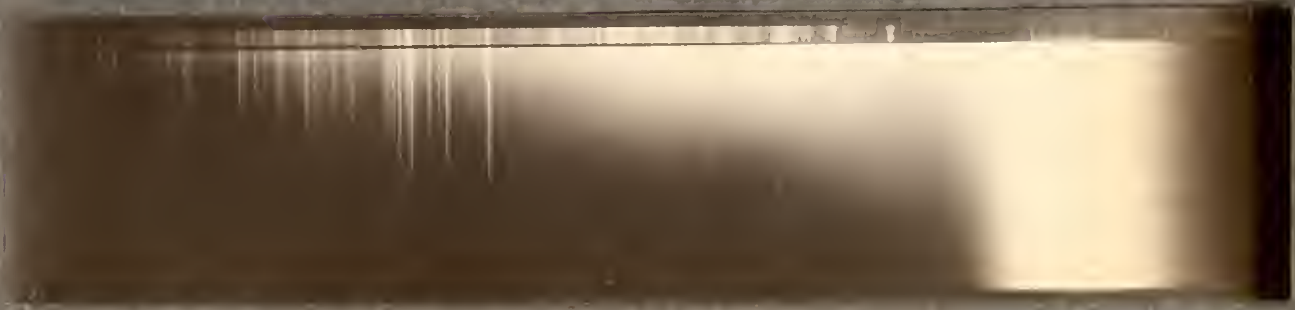
Fig. 78. See No. 140 page 140.

PLATE XXI.

Fig. 79. See No. 142 page 141.

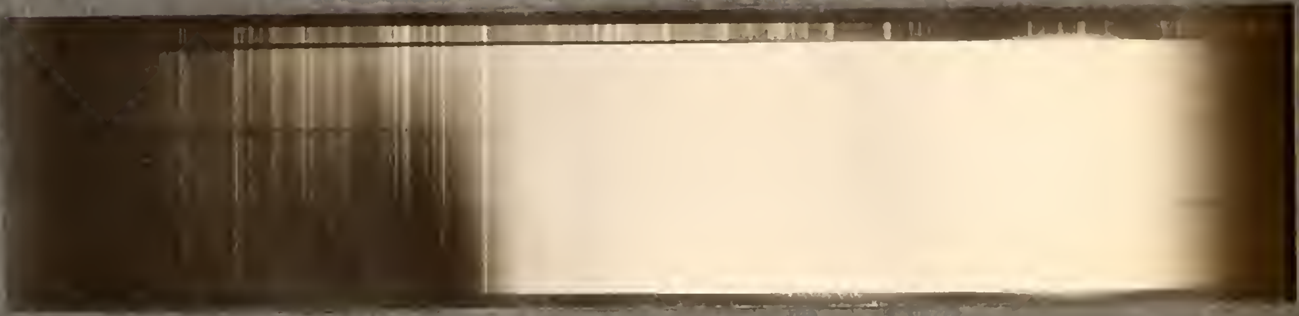

Fig. 80. See No. 146 page 143.

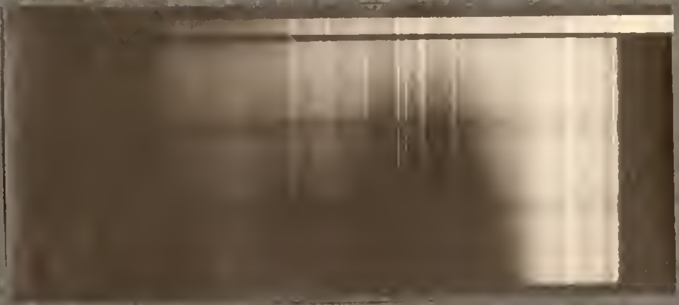

Fig. 81. See No. 146 page 143.

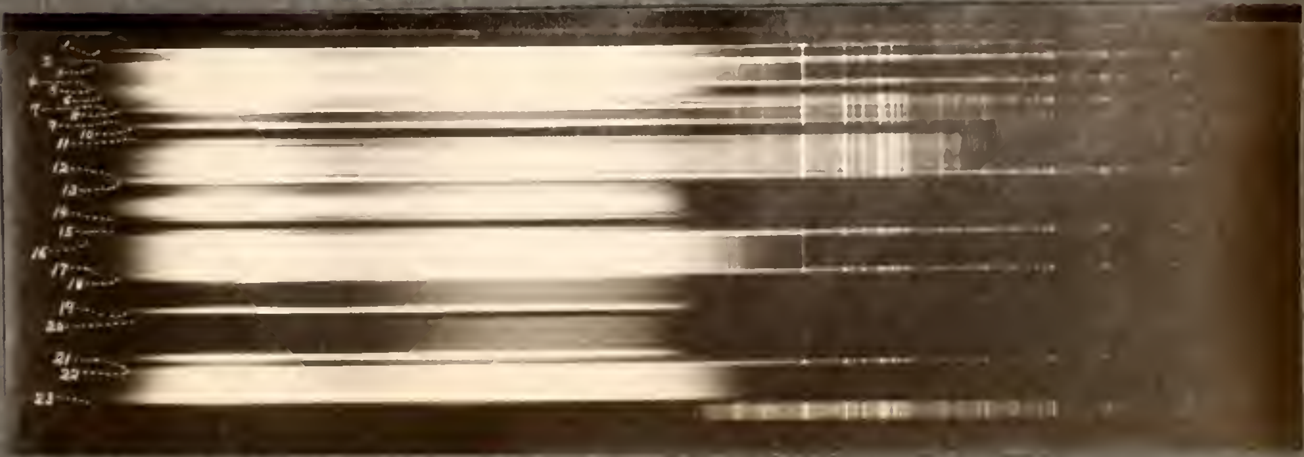

Fig. 82. See No. 148 page 144.

PLATE XXII.

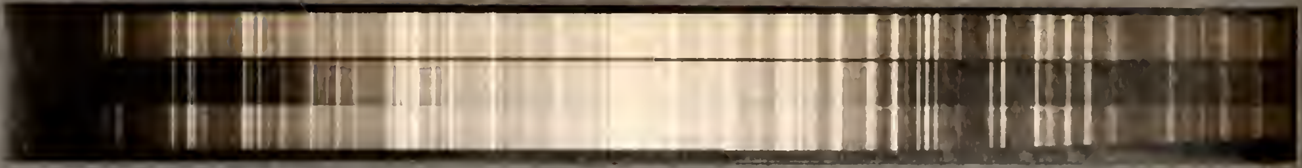

Fig. 83. See No. 150 page 147.

Fig. 84. See No. 152 page 148.

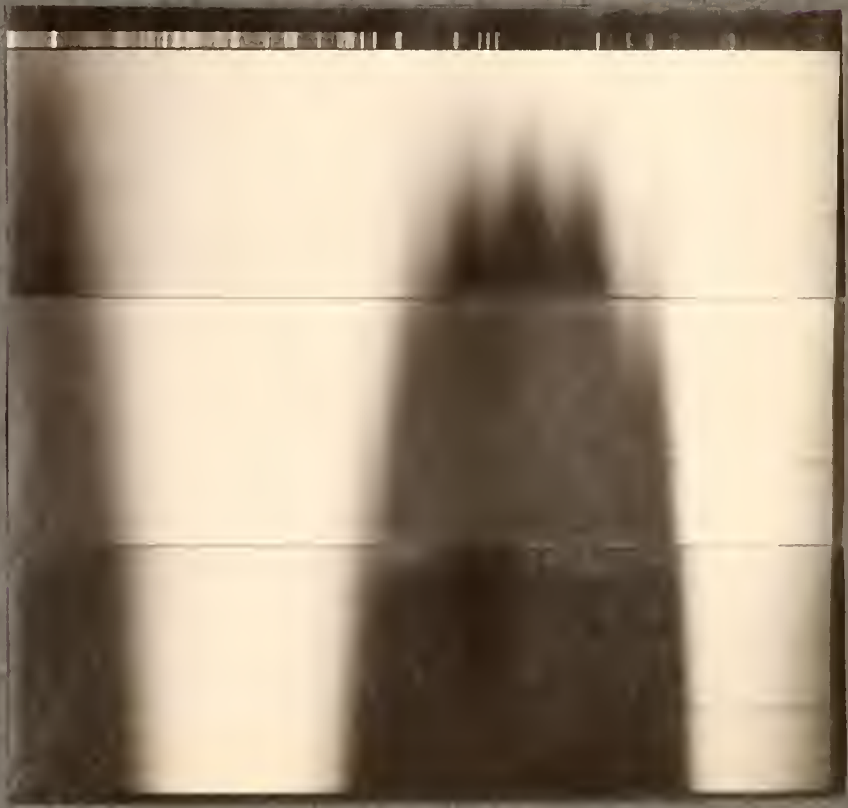

Fig. 85. See No. 152 page 148.

PLATE XXIII.

Fig. 86., See No. 152 page 148.

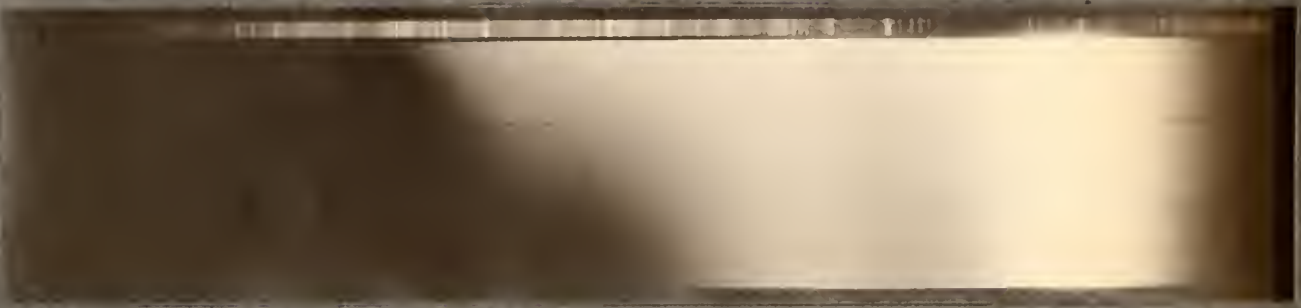

Fig. 87. See No. 153 page 150.

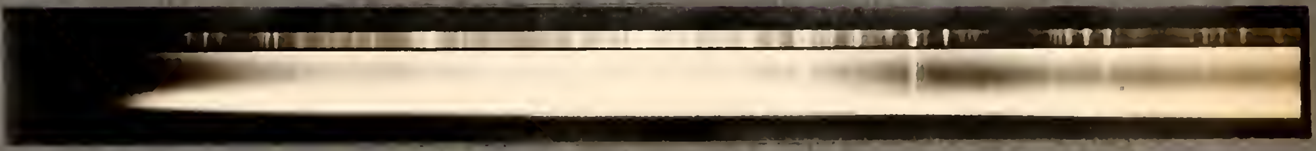

Fig. 88. See page 24.

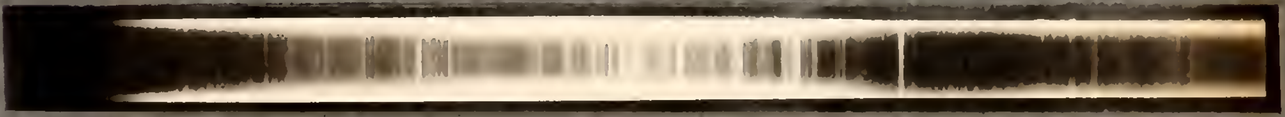

Fig. 89 see page 24.

Fig. 90. See page 24.

PLATE XXIV.

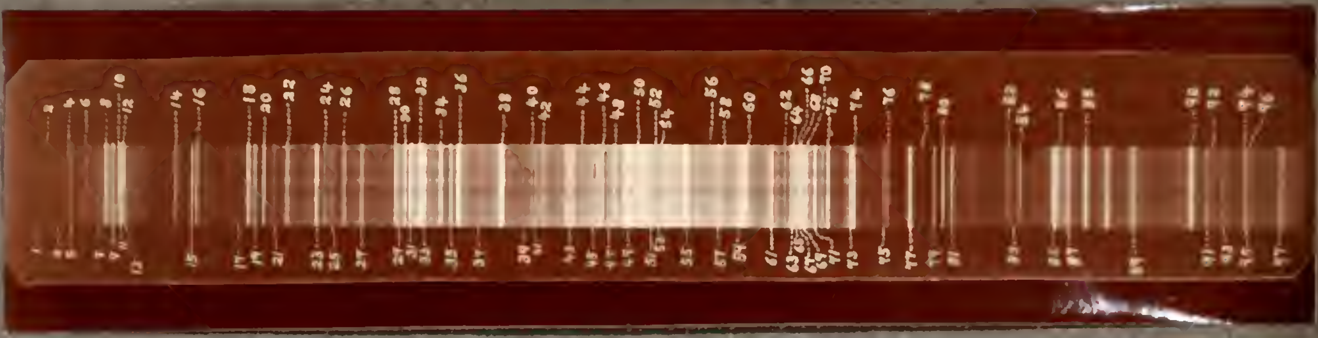

Fig. 91. See page 152.

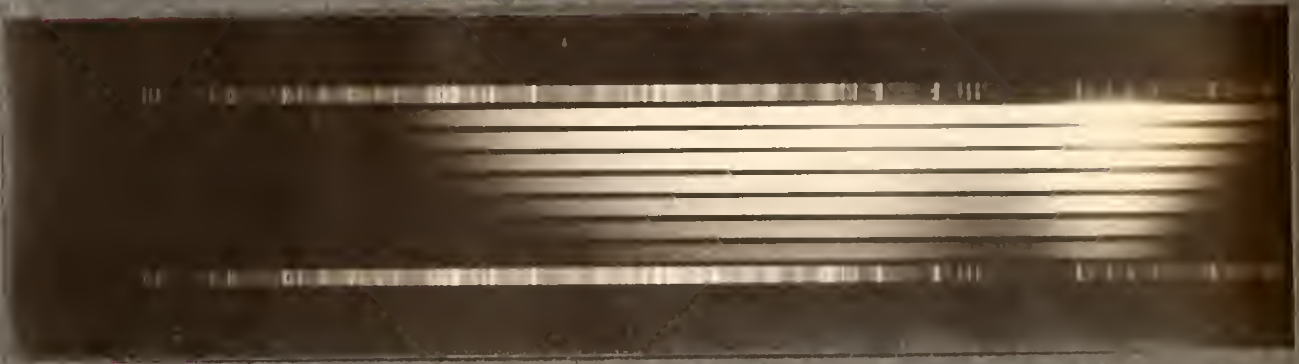

Fig. 92. See page 18.

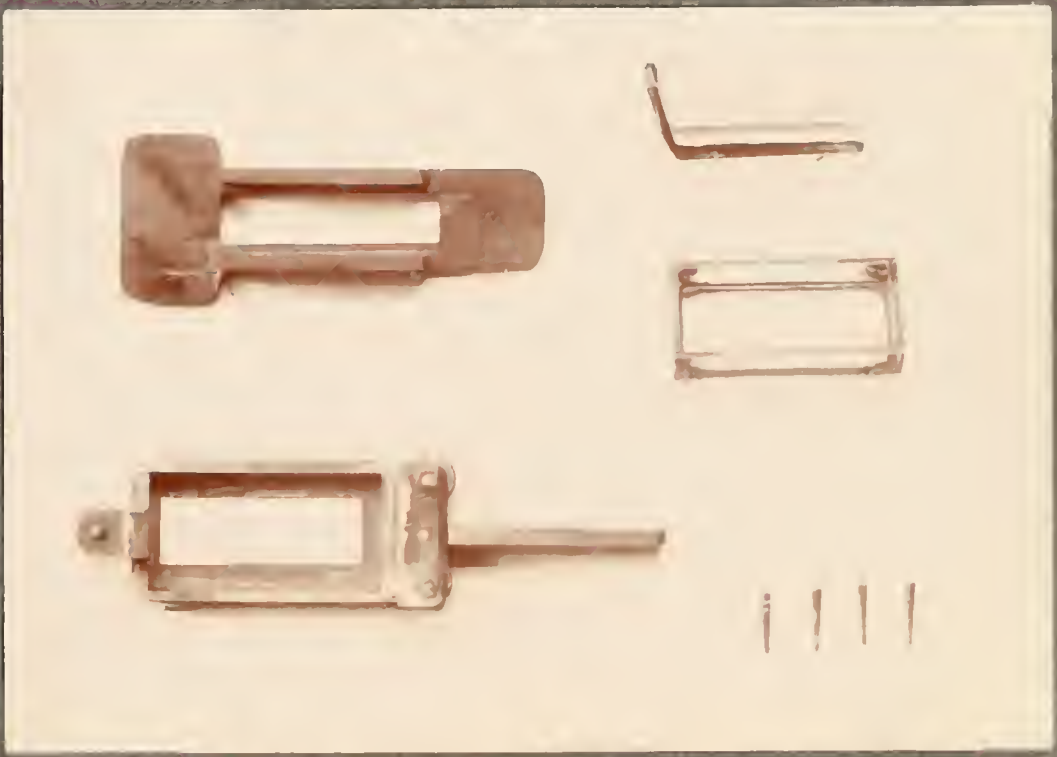

Fig. 93. See page 27.

Biography.

Horace Scudder Uhler was born in Baltimore, Maryland, August 5, 1872. He received his training preliminary to college work in the private school of Dr. E. Deichmann of Baltimore. His undergraduate studies were pursued in the Johns Hopkins University during the three academic years which ended in June 1894. In 1893-1894 he held a "Hopkins Scholarship". The degree of Bachelor of Arts was conferred upon him in June 1894. From September 1894 until February 1896 he was a graduate student in physics, mathematics and astronomy in the Johns Hopkins University. During the same interval of time he was a "Student Assistant" in physics. The remainder of the scholastic year of 1896 was spent by him as a teacher in the private school of Mr. W. S. Marston of Baltimore. The following year he was "Instructor in Physics" in the Academy of the Northwestern University at Evanston, Illinois. From September 1897 until June 1902 he was "Science Master" in the "University School for Boys" with Mr. W. S. Marston as Principal. Since this last date he has pursued advanced studies in physics, physical chemistry and mathematics in the Johns Hopkins University. During the interval 1904-1905 he held a Fellowship in Physics.